This is a digital copy of a book that was preserved for generations on library shelves before it was carefully scanned by Google as part of a project to make the world's books discoverable online.

It has survived long enough for the copyright to expire and the book to enter the public domain. A public domain book is one that was never subject to copyright or whose legal copyright term has expired. Whether a book is in the public domain may vary country to country. Public domain books are our gateways to the past, representing a wealth of history, culture and knowledge that's often difficult to discover.

Marks, notations and other marginalia present in the original volume will appear in this file - a reminder of this book's long journey from the publisher to a library and finally to you.

Usage guidelines

Google is proud to partner with libraries to digitize public domain materials and make them widely accessible. Public domain books belong to the public and we are merely their custodians. Nevertheless, this work is expensive, so in order to keep providing this resource, we have taken steps to prevent abuse by commercial parties, including placing technical restrictions on automated querying.

We also ask that you:

+ *Make non-commercial use of the files* We designed Google Book Search for use by individuals, and we request that you use these files for personal, non-commercial purposes.
+ *Refrain from automated querying* Do not send automated queries of any sort to Google's system: If you are conducting research on machine translation, optical character recognition or other areas where access to a large amount of text is helpful, please contact us. We encourage the use of public domain materials for these purposes and may be able to help.
+ *Maintain attribution* The Google "watermark" you see on each file is essential for informing people about this project and helping them find additional materials through Google Book Search. Please do not remove it.
+ *Keep it legal* Whatever your use, remember that you are responsible for ensuring that what you are doing is legal. Do not assume that just because we believe a book is in the public domain for users in the United States, that the work is also in the public domain for users in other countries. Whether a book is still in copyright varies from country to country, and we can't offer guidance on whether any specific use of any specific book is allowed. Please do not assume that a book's appearance in Google Book Search means it can be used in any manner anywhere in the world. Copyright infringement liability can be quite severe.

About Google Book Search

Google's mission is to organize the world's information and to make it universally accessible and useful. Google Book Search helps readers discover the world's books while helping authors and publishers reach new audiences. You can search through the full text of this book on the web at `http://books.google.com/`

TIN MINING,

DRESSING & SMELTING

CHARLETON

622.34
C478

BRANNER
EARTH SCIENCES LIBRARY

STANFORD UNIVERSITY LIBRARIES

RÖMER SHAFT HOUSE & PINGE, ALTENBERG.

TIN:

DESCRIBING THE CHIEF METHODS

OF

MINING, DRESSING, & SMELTING

IT ABROAD.

WITH NOTES UPON

ARSENIC, BISMUTH, AND WOLFRAM.

BY

ARTHUR G. CHARLETON,

MEMB. AMERICAN INSTITUTE OF MINING ENGINEERS; CONSULTING ENGINEER.

With Drawings carefully laid down to Scale,

CHIEFLY FROM ORIGINAL SKETCHES.

LONDON:

E. & F. N. SPON, 16, CHARING CROSS.

NEW YORK: 35, MURRAY STREET.

1884.

LIBRARY OF THE
LELAND STANFORD JR. UNIVERSITY.
a.46390
OCT 11 1900

PREFACE.

It may generally be said that nothing can advance the interests of those engaged in mining, more than the interchange of information legitimately gained by one and the other in its practical pursuit, provided that the facts placed on record are marked with a view to accuracy and attention to detail; for it is clear, that in order to conduct the affairs of a company with proper efficiency, a Superintendent must of necessity be more or less cognizant of all matters relating to those branches of his profession with which he has to deal; as should the property under his control, through the neglect of any source of real economy, fail to pay what under other circumstances it might, the fact alone of its even returning dividends does not *excuse* the faults of its administration, or prove that the mine is managed, as it should be, to the *best* advantage.

Disregarding the case of a wilful or careless omission of precautions, it is evident that such a condition of things can arise, through simple ignorance of the possibility of substituting a better system for the one being followed, as the faults that can generally be detected are for the most part attributable to a disregard of those *small matters* of detail, that the unassisted personal experience of no

single individual has any possible chance of compassing in these times of rapid progress.

Where the scale just turns, the substitution of one machine for another, a slight, perhaps *apparently* unimportant, modification in a process, or the arrangement of plant, by resulting in closer work, may bridge the difference from loss to profit, and yet be left neglected, simply for want of a precedent to go by.

Since it is clear then that the ordinary range of personal observation is too limited to be alone depended on, to guide the engineer in the difficulties he may have to encounter; and as he naturally can but seldom *intuitively* grasp and remedy for himself the defects which may be inherent to a particular line of policy; the Transactions of several Societies, as well as various monographs, have from time to time been published, with the object of describing whatever may be of interest, sufficiently fully and practically, to afford us as it were an artificial but sound acquaintance, with what is being done and noticed by others, in places outside of general reach.

Believing that Saxony and Bohemia come within the latter category, and that for want of publication, but little comparatively is known in England, about the conduct of tin mining on the Continent, my object will have been realised, if this treatise contains any technical information that may be of service to the professional reader, or that proves new to any one in search of particulars, on the subjects of which it treats.

Finally, besides acknowledging assistance received from reference to the writings of Richter, Kerl, Von Cotta, and Gaetzman on various points that escaped my notice when

collecting the notes that form the nucleus of the material I have been able to gather, I have gratefully to return my thanks to Messrs. Strickland and McNullty for the loan of sketches to compare with those of my own, from which the drawings of the mills and machinery have been elaborated, whilst, above all, I should specially allude to the kindness and courtesy of the German officials of the different works, in affording me facilities for acquiring whatever general information I desired or needed.

ARTHUR G. CHARLETON.

March, 1884.

CONTENTS.

ALTENBERG.

INTRODUCTION.

Statistics regarding the production of Tin in different countries—Tin in Saxony—Principal tin mines—Yearly output—Geographical situation—Local position .. .. Pages 1–2

CHAPTER I.

GEOLOGY.

The tin zone of the Erzgebirge—Nature and character of the rock-masses and ore deposits at Altenberg—Cassiterite—"Zwitter"—General composition—Percentage of tin present—Associated minerals — Structure — Occasional constituents — Stockwerks-porphyr—Peculiarities of the adjoining porphyritic granite—Influence exercised on the veins—Dark-bands—Removal and re-segregation of felspar—Conclusions drawn by Von Cotta regarding the origin of the deposits—Hydro-metamorphism—Theory compared with actual fact—Supported by the discoveries of Bischoff, Kjerulf, and Daubrée— Pseudomorphism—Effects of alkaline solutions—Relation apparently existing between tin-ores and particular kinds of country rock 3–6

CHAPTER II.

MINING.

Cause of the disaster that occurred at Altenberg in 1620—"The Pinge"—Character and dimensions— Compared with open workings in Wales and Sweden—System of mining involved—The Vereinigt-Feld mine—A long adit — Bruch-bau — Stehenden-Bruch — The Bruch-ort—Lebendigen-Bruch—The Schub-ort—Flugel-orts—Timbering—Sorting—Car-tracks—Output—Stockwerks-bau—A stock-work—Plan of opening up—Dimensions of chambers—Modes of attack—Precautions necessary—General appearance—Haulage—The Römer shaft—Why perpendicular—Fire-setting .. 7–11

CHAPTER III.

ORE-DRESSING.

The nature of the ore—Situation of the dressing-works—Physical advantages—General character and extent—Plant—Staff employed—Sorting on the dump—Fire *v.* "spalling"—Murbebrennen—Roasting in open-heaps—Mill No. 1 at Altenberg—Machinery—Absence of jigs—German stamps—Duty—Construction of the Battery—Power—Drop—Water-supply—Wear—Battery-slimes—Settling-boxes—Dimensions—Manipulation—Action—Products—The labyrinth—Dimensions—Products—End-percussion tables—System of working—Concentrates—Adjustments—Use of the "Unterfass"—The "tye"—Construction—Products—Guter-stein—Geringer-stein—Schwarz-stein—Abgangs-stein—Reasons for roasting .. .. Pages 12–20

CHAPTER IV.

ROASTING.

Character of the furnaces—Manipulation—Chemistry of the process—Drawing the charge—Furnace-dust—Sulphur compounds—Loss in roasting 21–22

CHAPTER V.

ARSENIC.

Arsenious oxide—How deposited—Clotting of the roast—New design for chambers—Collecting the crude arsenical dust—Refining the arsenic—System at Swansea—Description of plant employed—Arsenic kettles—Charging—Operating—Consumption of fuel—Regulating the temperature—Production of white-glass—Conditions to be fulfilled—Quality of the glass—Residues—Uses of arsenic 23–26

CHAPTER VI.

FINAL CONCENTRATION.

Washing on "the tye"—Removal of altered compounds of sulphur arsenic, and iron—Final washing on the inclined-table—Different stages of the operation—The Stein-trog—Working the Gefälle—Schwärze—Abgangs-stein—Adjustments and capacity of the nicking-buddle 27–29

CHAPTER VII.

EXTRACTION OF BISMUTH.

Leaching the concentrates—The leach—strength of the solution—The liquor—Precipitating—Chloride of bismuth—Crystallisation of bismuth—Uses—Statistics of production—Value—Removal of the leached concentrates to "the tye"—Final treatment with acid—Last washing with clean water—Proportion of impurities removed—Black-tin .. .. Pages 30–31

CHAPTER VIII.

SMELTING.

Shaft-furnaces used—Details of construction—The hearth—The fore-hearth—The Stechherd—The twyers—Furnace linings—Shape and proportions of the shaft—Bears—Dead-centres—Length of campaigns—Composition of the charge—Charcoal used—Preliminary treatment of the slags—Setting a furnace in operation—Draught—Loss in dust—Strength of blast—Comparison between blast-furnaces and reverberatories—Loss by sublimation—Loss by slagging—The advantages of the Spur or Gutter Ofen—Saving in fuel—Formation and composition of sows—Proper temperature—Indications of cooling—Skimming the slag—Filling the crucible—Regulating the temperature of the bath—Härtlinge—Difference between Hartbruch and Ofenbrüch—Furnace-tin (Werk-zinn)—The liquating plate—Liquation of the metal—Treatment of the residues—Liquation dross—Use of the Stechherd—Character and composition of the slag—Re-smelting or refining the slags (Schlacken treiben)—The slag refining furnace—Peculiarities of its structure—Brasque—Warming and blowing-in—The Eimer—The charge—Signs of good working condition—Impure slags—Chilling and washing the slags—Slag-tin—Proportion of slag to metal produced in ore-smelting—Roasting the härtlinge—"White-metal"—Casting—Temperature requisite—How indicated—Effects of neglect—Red-shortness—Cold-shortness—How to avoid—Quality of Saxon tin—Impurities in crude-tin—Difference between liquating and poling—Advantages of each system—How the "gangue" in the charge affects the process—Influence of iron and lime used as fluxes—Difficulties in the way of the tin smelter—How best overcome—Wolfram—Oxland's process—Analyses of various sorts of metallic tin—Effects of various impurities on the quality—Loss in Saxon smelting—Production of Saxony, compared with England—Review of the Altenberg system—Changes to be recommended 32–43

CHAPTER IX.

ZINNWALD.

INTRODUCTION AND GEOLOGY.

Position of the district—Structure of the rock-masses containing the tin deposits — Adjacent formations — "Greissen" — Composition — Relation to granite — Mineral beds or Flötze — Position — Number—Contents — Structure — Druses — Kaolin—Hornstone—Tin lodes—Character—Dip—Course—Filling—Apparent influence on the beds—Age 44–47

CHAPTER X.

MINING.

The Vereinigt Zwitter-feld mine—The Albert shaft—Depth—Position—System of development—Chamber-workings—Size—Character—Method of removing ore—Geological sections—Ribbon structure—Singular occurrence of wolfram bedded with mica—Position of winzes 48–50

CHAPTER XI.

TIN-DRESSING.

Proportion of tin in the ore brought to bank—Other minerals—Sorting—Tin ore—Wolfram ore—Tin dressing floors—Plant—Settling tanks—Outline of the process 51–52

CHAPTER XII.

TREATMENT OF WOLFRAM.

The wolfram dressing-house—Arrangement of machinery—Dimensions of "tye"—Tanks—Classes of settlings worked on end-percussion tables—The concentrates obtained—Drying—Packing—Uses of wolfram—Mushet-steel—Production of the Zinnwald works—Prices ruling in different years—Table-sands—The catch-pits—Influence of hand-sorting upon the process 53–55

CHAPTER XIII.

ABERTHAM.

INTRODUCTION AND GEOLOGY.

Geographical position—Early discovery—Proprietorship—A master-lode — Width — Development — Gunnisses — Over-hand stopes — Under-hand stopes—Timbering—Packing .. Pages 56–57

CHAPTER XIV.

ORE-DRESSING.

Arrangement of the works—Power—Water—Steam—Cornish stamps—Weight—Frequent breakage—Speed and drop—Screens—Size of mesh—Position—The bed—Pointed-boxes—Size—Capacity—Water supply — Discharge — The tank system — Dimensions — Classes of settlings—The end-percussion tables—Theory of the separation on tables—Previous preparation of the ore necessary—Influence of the water current—Inclination of the bed—Proportion of ore in the pulp—Distribution of the slimes—Teazers and agitators—Adjustments of the pegging-board—Effects of the blow—Rapidity of successive shocks—Length of shove—Initial velocity of the striking rod—Period of rest at the end of the stroke—Result of the blow at the end of the return—The timbre of the shock—Means adopted for regulating the inclination and tension—Management of the tables—Ordinary waves—Cross waves—Deposition of settlings—Cause and means of remedying incompactness—Hummocks and ridges—Longitudinal furrows—Irregular settlement—The scraper or kiste — Indications given by strings (Germ. "Schnurs")—Colour of the deposit—Colour of the pulp—Striking-blocks—Rigid—Elastic—Necessity of checks by assay—Manipulation of the tables at Abertham—Side or continuous percussion tables—Construction of the Rittinger table—Nature of the blow, compared with that of an end-percussion table—Essential points in working them successfully—Effects of varying loads—Governors—Automatic cut-offs—Adjustments—Leaching the Ober-erz—Treatment of "Schaufel" 58–75

CHAPTER XV.

SMELTING.

The Abertham Smelter—Plant—Dimensions of furnaces—Fan blower—Treatment of furnace slags—The liquating furnace—Description of the operation—Casting the metal in blocks 76–77

EXPLANATION OF THE PLATES 78–83

DRESSING-TREE AND GRAPHIC PLAN OF THE SMELTING PROCESS AT ALTENBERG.

ZINNWALD DRESSING-SCHEME.

TREE SHOWING THE DRESSING AND SMELTING PROCESSES AT ABERTHAM IN DETAIL.

SKETCH MAP OF ALTENBERG .. .. *At end*

PLATES FROM I. TO X... .. .. *At end*

TIN:

MINING, DRESSING, AND SMELTING.

ALTENBERG.

INTRODUCTION.

OUT of about 16,430 tons of Tin, which amount is said to represent, as nearly as possible, the average annual production of the world, the proportions contributed by different countries, according to Kerl,* are approximately as follows :—

	Tons.		Tons.
East Indies	7,500	England	7,200
Peru	1,500	Saxony	130
Bohemia	60	Spain	40

The largest portion of the supply credited to the state of Saxony in the estimate given, comes from a group of mines located in the district of Altenberg, on the confines of Bohemia, about 20 miles due south of Dresden, which, from data derived from official returns, appear to have produced 105 tons 738 lbs. of refined tin, worth 9171*l.* 8*s.* 3*d.* = $44,637 in 1880, as against 97 tons 1318 lbs. in 1879, worth only 6864*l.* 8*s.* 8*d.* = $33,409, in consequence of the

* 'Metallurgischen Hü.tenkunde,' 2 Band. S. 766.

price being then 16*l.* 5*s.* = $79 10c. a ton lower than in the following year.

As the nearest line of railway is 12 to 15 miles distant from the town of Altenberg, situated in the immediate neighbourhood of the works, the only means of communication with them is by vehicle, following the chaussées that start from Edle-Krone, Bienenmühle, and other points.

The two principal properties in the district, which are contiguous, and are known as the Vereinigt-Feld and Zwitterstocks Erbstolln, together yield the bulk of the tin obtained from the locality, as in 1880 only 2 tons 334 lbs., out of the total amount lately mentioned, came from other mines.

CHAPTER I.

GEOLOGY.

THE rocks around Altenberg, where tin is found, penetrate the gneiss of the Erzgebirge in various places, over a belt of country 2 to 4 miles broad, that extends for 25 miles, from Altenberg on the east, to the Fichtel Berg on the west.

Near the former place, which has given its name to the entire district, "the mineral" (cassiterite) occurs in deposits of two distinct sorts; in the one case *impregnated* through a mass of rock (locally known as "zwitter") that measures about 1312 feet across its outcrop; in the other, associated with hematite, quartz, and other gangue, in a number of small but regular fissures, averaging rarely more than 8 inches in width. These latter form a complete network of veins through the same formation of "zwitter" alluded to, which is enriched wherever they traverse it, although the veins themselves now hold but a comparatively small amount of tin. On passing into the adjoining porphyritic granite, most of them, however, appear to become richer, and are frequently found with a parting of red clay; whilst, on the other hand, they cease to be productive, where they enter the next adjacent eruptive masses of quartz-porphyry and syenite-porphyry, which so imperceptibly merge into one another, that no distinct line of demarcation can be traced between them.

The zwitter is a dark-grey or greenish coloured rock, frequently almost black, that holds one-third to one-half per cent. of tin, and is of remarkably fine texture, composed

essentially of quartz with chlorite or lithia-mica and cassiterite (tin-stone); specular-iron, wolfram, mispickle, and traces of other metallic sulphides, in addition to several non-metallic minerals, being also sometimes found amongst its constituents. The quartz, which is in an amorphous condition, is, it should be observed, the only one of its components except cassiterite that can be plainly distinguished by eye-sight alone. This peculiar mineral combination only differs in fact from typical "greissen," of which it is a variety, by its having a finer texture and darker colour (partly owing to the predominance of chloritic mica), and through the presence of cassiterite, with small proportions of the other minerals that enter into its composition, as *occasional*, rather than as essential components.

These components include, besides those already mentioned, bismuth (native), bismuthine, molybdenite, copper and iron pyrites, and fluor-spar, but they can be seldom recognised separately, except in the irregular pockets and strings of quartz that penetrate the rock in different directions; and, as the term is misleading, it should be mentioned that the name of "Stockwerks-porphyr," given to the "zwitter" by the miners, is obviously a misnomer, since it possesses neither a true felsitic base, nor properly developed crystals.

The porphyritic-granite, of which the neighbouring rock-mass consists, is fine grained, and of a reddish-yellow colour, being very rich in pink felspar, and it is noticeable that the stanniferous strings and veins of quartz that, as beforesaid, are merely extensions of those traversing the formations on either side, in which they are in the one partly, and in the other entirely barren, here, not only carry ore in paying quantities (being generally most highly mineralised where they run east and west), but are also bounded on both walls by a broad dark band or zone of rock, that more or

less resembles "zwitter," and, like it, is impregnated, though to a less extent, with cassiterite. Further, the felspar, that has apparently been entirely removed from the bands themselves, is, or seems to be, more than ever predominant in the granite into which they gradually merge.

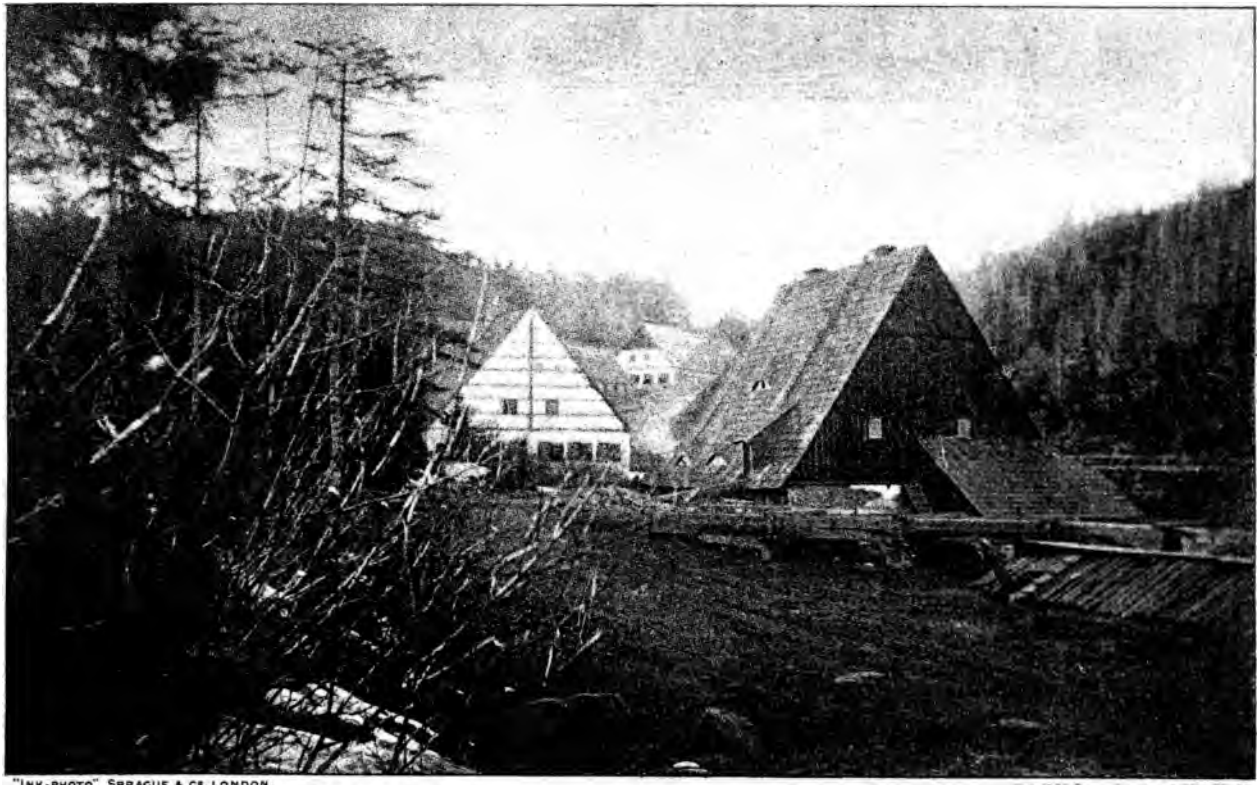
These facts, when considered collectively, point to the conclusion formed by Von Cotta and others, who have studied the geology of the district very carefully, that the "zwitter" is merely an altered form of what was once a granite, similar to that at present next it, which became impregnated with solutions of silica and tin, in combination with other elements, whilst at the same time it was subjected to the influence of heat; this hydro-metamorphic action (as it may be called) having doubtless had the effect of removing the felspar also from the original rock (through the channels formed by the veins), and of re-depositing it in places, where small quantities already existed, at no great distance from the points from whence it was thus derived.

Such a theory would account for, and be in keeping with, the small amount of tin in the veins in one place, and its comparative abundance in another; the existence of "the dark bands," the preponderance of felspar in the unaltered granite, and the presence of cassiterite disseminated through the "zwitter," in which it exists at the present time, however, doubtless in somewhat larger proportion than it did formerly, in the other formations close by, now barren, where the mineral has been segregated in the veins instead.

In the "Stockwerks" that will be spoken of further on, this supposed process of substitution, if the theory be correct, is seen most perfectly developed, and as Bischof has proved that tin-stone can be dissolved in water containing alkaline carbonates, whilst Kjerulf and Daubrée have shown

that it may be deposited either from solutions, or gaseous emanations; coupling these facts with its known occurrence in some of the Cornish tin mines, as an actual pseudomorph of felspar, it seems only reasonable to infer that alkaline waters, charged with tin, derived in the first instance from the adjacent formations, actually did penetrate the "zwitter" through the network of fissures which were open at the time, dissolving and removing the felspar, and leaving cassiterite in its place, whilst filling up what are now the veins with quartz and other minerals.

It is worth mention, in bringing these few remarks upon the geology of the district to a conclusion, that the relationship which may be noticed here as elsewhere between tin-ores and rocks of a granitic character seems to be universal, as the former are rarely if ever found far from the latter, whilst seemingly the most productive lodes are generally those situated near the junction of granite, syenite, or rock of that class with a metamorphic formation, or, as sometimes happens, with ancient sedimentary deposits.



"INK-PHOTO", SPRAGUE & Cº, LONDON.

E. & F. N. Spon, London & New York.

SMELTER & DRESSING FLOORS, ALTENBERG.

CHAPTER II.

MINING.

A NUMBER of shafts are said to have been sunk at different times upon these remarkable tin deposits at Altenberg; but five of them were destroyed in 1620 by a sudden and unexpected subsidence of the surface taking place, owing to weakness or unsoundness in the timbers and pillars left underground to support the weight of the superincumbent earth and rock, which, in falling in, spread destruction through the workings, and formed a crater-like opening, or "open-cast," known as the "Pinge,"* 930 feet long, 600 feet wide, and 190 feet deep, encircled by perpendicular walls, and filled at the bottom with a bed of débris, that has been proven to a depth of 480 feet, without finding bed-rock.

The existence of this "open-cast," which bears no slight resemblance to the excavations for copper at the Parys and Mona mines, Anglesea, and others for iron-ore, in Sweden, has given rise to a peculiar system of "getting" mineral which one finds pursued in some of the workings of the Vereinigt Feld Mine, that has been operated since 1457, and to which access is obtained, either by the Römer shaft, 657 feet deep, or by an adit, commencing near Geising, that intersects the deposits 272 feet below the surface.

* The engraving shows the top of the "Pinge" indistinctly in the background. The faintness of the print is entirely due to defects in the original photographic negative, which was taken just as the sun was about to set, for want of any other opportunity.

The method of winning ore, to which special allusion has been made above, is known as "Bruch-bau"; and, for reasons that will be obvious later on, this system can only be practised in the comparatively deep workings.

It consists in driving galleries 6 × 8 feet from firm ground (A), Fig. 1, in the direction of the "Pinge," until as the face of the drift approaches the border of the broken fragmentary débris (E) in the "open cast" (it is intended to traverse diagonally) disturbed and disjointed rocks, "Stehenden-Bruch" (B), are met with, "sets" of timber have to be put in, and the level is in what is called the "Bruch-ort." Thence it is pushed forward (still using explosives) until it is well within, and under the actual body itself of breccia and detritus, "Lebendigen Bruch" (E), a position that requires timbering and lagging of extra strength, to keep it open and prevent "a cave," but which, when once reached, enables the miners to get the ore, by merely picking, raking, and shovelling it inwards at "the face," called the "Schub ort," where a fresh supply keeps constantly rolling in, forming a sort of natural talus (D), Figs. 1 and 2, as fast as that in front is removed.

Ore obtained in this way is of course mixed with much waste which is utterly worthless, and it has therefore to undergo a careful sorting, before being sent to bank; but the supply obtained is seemingly so inexhaustible, that a "Schub ort" will frequently continue to afford fresh material for weeks, or even months, and when it ceases to do so, all that is necessary is to penetrate further into the mass of débris, by timbering forward, until a point is reached where a continuous natural supply re-commences. But in order to augment the number of working faces, when the output requires to be increased, side-drifts or cross-cuts, "Flugel-orts" (*c*), Figs. 1 and 3, timbered like the main-galleries, are

frequently started out from the latter into the "Lebendigen Bruch," at safe distances apart from each other.

With this plan of working, the chief points to be looked to are, that the galleries do not run under one another at different levels, and that no vacant spaces (H), Fig. 1, remain open above the timber, as a fall of rock from any height above would inevitably do much damage in the drift.

Two men are usually employed in each face, one getting, the other timbering or sorting as occasion requires; whilst a third wheels the ore in barrows to the shoots, placed at intervals along the main car-tracks.

A gang in this way is able to handle from 3 to 4 tons of ore in an eight-hour shift, and the facility with which the mineral is obtained (notwithstanding the cost of timber) makes "Bruch-bau" more in favour than any other system at Altenberg.

Another method that may still be seen in operation in these mines is the so-called "Stockwerks-bau," but it can only be employed in those parts of the deposit where the zwitter is *impregnated* with cassiterite in sufficient quantity, or a network of small veins bunch together; for it should be explained, that the mere presence of cassiterite does not alone constitute a stock-work—Germ. Stockwerk—as the term is applied only to those centres of enrichment where the rock, though comparatively poor, appears to be rich enough to be mined at a profit. Stockwerks-bau would indeed never be followed, unless considerable portions of the rock were barren, and the value of the pay-rock comparatively so small and variable that large quantities must be got out to make it pay; and, from circumstances outside of the miner's control, no regular plan of working can be maintained underground.

In mining by this system at the present time, drifts are

driven from the Römer shaft at every 63 feet in depth with the aid of explosives; and as soon as the deposit is reached, cross-cuts are started from the main levels in safe ground, towards supposed points of enrichment, where the ore is worked out generally by over-hand stoping, in floors one underneath the other, each consisting of several approximately circular chambers, which are often 40 to 50 feet in diameter, and 35 to 45 feet high.

Having in the first instance made one of these excavations, the next step is to drive one or more galleries in any desired direction, just sufficiently long to leave a safety pillar of comparatively poor rock, usually 15 to 25 feet in diameter, between the last chamber and the nearest point where ore can be found that can be worked in a similar manner; and thus a series of chambers are formed, irregularly placed with regard to one another, on the same storey or "Stock," and separated by what may be considered as merely massive pillars of "country rock."

In occasional instances, where it has been desirable to follow a shoot of ore downwards, below any deeper workings near it, the floor has been worked out by under-hand stoping until down many feet below the lowest drift by which access can be obtained to "the Stock"; so that you descend to the bottom, as it were, by a flight of steps, starting from a ledge that runs partly round the side of the chamber, and connects with other excavations at the original level of the storey.

A point of great importance in carrying out this system, if great risk would not be incurred, especially when the chambers are of large size, is to keep the pillars in the different floors, which are separated by about 9 to 15 feet of solid rock, as far as possible directly underneath one another; and it is presumed that the neglect of this precaution was the direct cause of the disaster that resulted in

forming the "Pinge." Occasionally, however, the floor between superimposed chambers has been purposely broken through, by knocking away the supporting pillars; and in such cases one may notice the open ends of what were once short galleries on the upper floors, that have now become inaccessible except with ladders.

The different floors are formed by commencing near the surface and working downwards; and there are probably few more curious or striking sights to be seen underground, except possibly in some of the salt workings of Cheshire and Stassfurt, than is afforded by a "Stock-werk" of this kind, in which knolls of rock *in situ* (too poor to be removed), and fragments of ore of all sizes that have fallen from the roof, are strewn about; whilst the darkness overhead is almost impenetrable in the dim light given by candles, owing to the height of the arched vault above you.

An iron cage, operated by a water wheel, is used in the Römer shaft, which is sunk perpendicularly, at variance with the general practice prevailing in the metal mines of Saxony, in order to avoid disturbed and dangerous ground, and because of the character of the deposit it is intended to open up, which does not under any circumstances favour an incline.

The oldest method of getting the ore at Altenberg was by fire-setting, as at Rammelsberg, with a "Pregelkatze"; * but since it has long been abandoned, it is not necessary, I think, to do more than mention the fact.

* An iron frame, on which the wood set fire to was heaped.

CHAPTER III.

ORE-DRESSING.

THE ore from the mines, which carries tin, arsenic, and bismuth in paying quantities, as well as some molybdenum, after undergoing careful sorting, is taken to the dressing-works, situated together with roasting-houses and a smelter in a narrow valley (see sketch map), about one mile in length, and of but slightly varying width, from its commencement at the Römer shaft to its termination near Geising, in which direction there is a very regular down grade all the way.

Its sides are in places abrupt, in others rounded into bluffs, formed of a coarse porphyritic granite (remarkable for its large crystals of pink felspar), and are in many parts clothed with fine forests, mostly of pine, that afford some of the best timber for mining purposes; whilst a road conveniently situated for giving access to all parts of the property, and a stream which supplies the necessary water and power for the machinery in the mills, render the location a very suitable one for the purpose for which it was chosen.

The works devoted to the treatment of ore are some of them constructed of wood (a rare thing in Germany), with roofs pitched at a very steep angle on account of the heavy snowfall, and comprise twenty-seven separate buildings devoted to stamping and washing, two roasting-houses, two furnace-buildings, bismuth-works, shaft-houses, offices, repair-shops, smithy, stores, and saw-mill.

The stamp-houses are furnished altogether with 1386 head of stamps.

The dressing-floors contain 67 tyes, 84 end-percussion tables—Germ. Stossheerds—and 42 inclined-tables—Germ. Liegendeheerds—besides settling-tanks, vats, &c.; whilst the roasting-houses have two reverberatories, and the smelters a similar number of blast furnaces, but only part of this plant* is now running regularly, giving employment to about forty boys and fifty men.

As the handling of the ore is identically the same in all parts of the works, a description of its treatment in one building of each kind will be sufficient.

The ore having been brought to the surface, varying as it does in size from sweepings to blocks weighing several hundred-weights, is dumped, screened, and sorted; and all under 1½ inch in diameter that passes the grizzlie is sent direct to the stamps, whilst the very large masses are split by fire into pieces, which can afterwards be broken with sledges or by "burning in heaps" to a proper size.

The method of doing this is so simple and primitive that it hardly demands description, the lump of ore to be operated upon being merely set on two or three iron bars raised on smaller stones a foot or so above the earth, in any convenient spot on the "sorting ground." A fire of resinous wood is then lighted, and kept up underneath it, until

* The prominent absence of "*jigs*," which may be noticed at Altenberg, is due to the grain of the cassiterite in the ore of this particular locality being of a notably fine and even grade, which would not permit of their economical employment. For, although the judicious use of the class of machinery in question will often diminish loss in dressing, where there is a *proper preliminary classification*, in such a case as this, any attempt at jigging would obviously effect no saving, if indeed it did not tend to operate the other way.

For the same reason, the stamp batteries are arranged so as to enable the cassiterite to escape *as far as possible* without further comminution. The chief functions of the battery in this instance being rather to rid the mineral of its surrounding stony envelope.

it cracks and splits, under the disintegrating force of steam and unequal strain; a method which is probably cheaper and less dangerous to employ for breaking the larger blocks obtained in "Bruch-bau" than powder or dynamite would be.

Sometimes also, instead of spalling the bigger fragments obtained in the manner just described, fire is used in another way to complete the work it has already begun, particularly when the run of ore happens to be of a specially hard character, difficult to stamp raw, when what is called "Mürbe-brennen" is resorted to, in order to make it more friable. This consists in piling the ore on the ground in a heap, 36 feet square and 1 foot high, with a layer of chips 4 to 6 inches deep spread above, and roots and fagots stacked on top to a depth of nearly 2½ feet. Side walls 3 feet thick are then built around the edge of the heap forming the foundation, so as to surround the wood, on which lumps of ore, averaging 8 inches to 1 foot in size, are piled to a depth of 4 to 5 feet, and the top is finally covered with a thickness of 1 foot of smalls, about as large as a man's fist.

The burning lasts two days, the larger lumps falling to pieces; but if not yet small enough, or in a proper condition for stamping, they are burnt a second time.

Open-heaps—Germ. Freien-haufen—are again (though merely as a means of roasting) sometimes made use of, and are formed in the usual way of a bed of wood 14 to 16 inches thick, overlaid with 2½ to 3 feet of tin ore, and on top of all 4 to 5 inches of small coal.

Mill No. 1, Fig. 4, which is a type of most of the others in the valley, except as regards the relative position of the stamp-house and dressing-floors, has a plant of 120 stamps, 8 settling-tanks, 4 end-percussion tables, besides 2 dissolving tubs for the extraction of bismuth, and slime-pits outside the building.

The stamps are of the ordinary German pattern, Fig. 5, and are arranged in eight batteries, containing three sets with five heads in a set, weighing, stem and all, 250 lbs. apiece, and are capable of crushing about 11 to 15 cwt. of roasted zwitter, 8½ to 9 cwt. of raw, or 10 to 11 cwt. of raw and roasted zwitter mixed, per head, in 24 hours.

Figs. 5 and 6 will give a general idea of what such a battery is like. The most interesting feature in its construction is the coffer, which has a wooden foundation, with a bed of zwitter (A) 24 inches deep on top, that is stamped till it becomes firm and solid, and is 18 to 20 inches below the bottom of the opening (B) in front of the stamps, covered with interlaced pine boughs, that act as a screen.

A separate hopper (C) supplies ore to each set of heads, and is provided with the usual feeding arrangement, common to most wooden batteries, of a shoot (D) and striking block (E), the latter receiving successive blows at each fall of the middle stamp from the tappet at the back of the middle stem.

The stems measure 6 × 8 inches, and are made of beech wood.

Power is transmitted to each battery by a separate water wheel, and the stamps, which have a drop of 15 inches, and require about one-third of a cubic foot of water per minute, are run at different speeds when crushing different kinds of rock: with raw zwitter, falling 45 times per minute; 38 to 40 times with roasted; and 24 times per minute with "Abgang-stein" and "Schwarze." *

The heads are of wrought iron, weighing, when new, 110 to 120 lbs., and last 2 to 3 months; but are by that time reduced to a mere shank,† weighing only 15 to 20 lbs.

* Terms explained pp. 28 and 29.

† A most reprehensible practice, that materially affects "the duty" of the battery.

The sands and slimes, after leaving the battery-coffers, flow along wooden gutters (E), Fig. 4, set in front of each battery, and emptying into a main gutter (F), Figs. 4 and 7, that distributes them to a series of settling boxes—Germ. Poch graben—(G), four in number, standing side by side, and measuring 22 ft. 4 in. in length, 3 ft. 8 in. in width; and 1 ft. 11½ in. in depth. They are arranged as shown in the figures, with an overflow slit, *h*, at the top of the end board, which is also pierced with two holes, one beneath the other, that can be stopped with plugs (C C); whilst on the outside there is an iron shoot *l* directing the slimes escaping from the end of each box, into a labyrinth —Germ. Mehlfuhrung—(H), placed at a lower level.

The action of the boxes is more sorting than concentrating. Their manipulation is most simple, the workman merely letting one fill, whilst the others empty, allowing a full one to rest for half an hour, so that the material in it can settle, then opening the top plug-hole to allow the lighter slimes to escape, and finally clearing what remains, by knocking on the floor of the boxes with a wooden pole, admitting clear water, and opening the lower holes; taking care, however, the while, not to knock with the pole near the head of the box, for fear of mixing the fine with the coarser settlings.

The products resulting from this treatment are headings, middles, and box-slimes; occupying each respectively a third of the length of a box, from its head to its foot, whilst the lighter ore and tailings pass on to the labyrinth (H) beyond.

After traversing the "grabens" that form the labyrinth, consisting of eight settling-tanks, each 14 feet long, 2 feet wide, and 2 feet deep, any ore still in suspension in the current escapes to the slime-pits—Germ. Sumpf—Fig. 8, outside the building; whilst the ore that settles in the

boxes and tanks, the box-headings excepted (as they are treated at once on an inclined table, Fig. 20), go for further treatment to wooden end-percussion tables (A), Fig. 4 and Fig. 9, which, in order to distinguish each separately, I have called 1st, 2nd, 3rd, and 4th, in the description that follows.

The 1st table, Fig. 4, is devoted to the preliminary concentration of the middles and box-slimes, coming from the boxes (G), and yields headings (consisting of the upper two-fifths of the settlings deposited upon the table) that are collected, and tailings (what *remains upon*, as well as flows off, from the *lower* end of the bed) that are thrown away, or go of themselves to waste, the same table being afterwards used for washing the headings resulting from the first washing a second time, by which more highly concentrated headings are obtained, with tailings as before.

The 2nd table, Fig. 4, treats the concentrates resulting from the final washing on the 1st table over again, once or twice, and finally gives comparatively clean and rich headings, middles, and "Unterfass," * that must be re-washed, and tailings that are valueless (see "tree" of the Altenberg dressing-process).

The 3rd table is reserved for concentrating the settlings taken from the labyrinth (tank-slimes), or, as occasionally happens, from the slime-pits (pit-slimes), when the latter are now and then cleaned; following out the same course of treatment, as that pursued with the richer settlings on the 1st table, whilst the 4th table further concentrates the products of the last washing on the 3rd table, by repeatedly passing those portions that are already partially enriched by their previous treatment, as many times more over it as may be necessary for them to acquire a sufficient degree of concentration.

* A term that will be found explained on p. 18.

Having traced the ore thus far then in its course through the mill, before following it further, I must digress for a moment, to say a few words upon the adjustments that have to be given the tables, in order to enable them to properly work the different grades of ore in various stages of concentration, which have to be dealt with individually (as already described), each in a more or less different way.

The practice at Altenberg seems to be to give the 1st and 3rd tables 26 to 27 blows a minute, whilst the 2nd and 4th are run at 32; and to allow the 1st and 2nd tables (as the ore treated on them is comparatively coarse) an inclination of 1° to 3½°, as compared with the 3rd and 4th, which, working fine, vary from the horizontal to a slope of three-quarters of a degree.

The tension ranges from 1½° to 4°, and when a table gets nearly full, the strength of the blow is somewhat reduced.

It is also customary to use "the Unterfass" or box (A), Fig. 9, at the foot of the table, to catch the tailings coming from the coarser concentrates, when the latter are undergoing final treatment on the 2nd table, as the overflow, otherwise escaping along the gutter (*a*), Fig. 9, would carry with it a certain amount of cassiterite, which is better caught in this manner (as it can be collected at once, and washed with greater profit) than if allowed to go to the slime-pits.

The presence too of arsenical-pyrites, or mispickle, Sp. Gr. 6·3, occurring as it sometimes does in considerable quantity in the coarse grades of concentrates, often gives rise to a good deal of trouble, owing to its not being stamped as fine as the tin, for it is then liable to collect in a heap at the head of the table, and can only be dislodged by the use of a scraper—Germ. "Kiste"—since to increase the strength of the blow, as a means to the same object, would entail too large a loss of fine cassiterite, that would be carried away as well.

Additional particulars, regarding the requisite length of stroke, and consumption of water per minute, as well as the capacity of the percussion tables at Altenberg, when working different grades of ore, are given in the subjoined table :—

Grade of Ore.	Length of Stroke.	Quantity required per minute.		Time taken to fill "a table."
		Slimes.	Water.	
Coarse concentrates *...	4 inches.	$\frac{3}{8}$ of a cub. ft.	$\frac{1}{4}$ of a cub. ft.	3 hours.
Middles..	3 ,,	$\frac{1}{4}$,, ,,	$\frac{1}{4}$,, ,,	4 ,,
Slimes (box)...	$1\frac{3}{4}$,,	$\frac{1}{4}$,, ,,	$\frac{1}{4}$,, ,,	6 ,,
Slimes (tank)	$\frac{1}{2}$,,	$\frac{1}{4}$,, ,,	$\frac{1}{5}$,, ,,	12 ,,
Slimes (pit)	$2\frac{1}{2}$,,	$\frac{1}{4}$,, ,,	$\frac{1}{4}$,, ,,	24-48 ,,

* From previous "washings."

At the conclusion of the last washings only a narrow strip of sand is left at the foot of the 2nd and 4th tables, and as it is too poor to treat again, it is thrown away, whilst the rich headings higher up are still further concentrated on a "tye"—Germ. Schlämme-graben—Fig. 19,* 16 ft. 10 in. long (including head board), 15 inches broad, and 15 inches deep; which yields (*a*) tye-headings, and (*b*) half-clean concentrates; the latter settling at its lower end have to be again washed on an inclined-table, Fig. 20, when they give an additional quantity of good †-concentrates, distinguished as "Guterstein," "Geringer-stein," "Schwärz-stein," and "Abgangs-stein," according to circumstances explained hereafter.

The tye-headings, together with the several other sorts of good-concentrates enumerated, as soon as a sufficient amount has been collected, are removed in boxes to the roasting-houses for further treatment, the object being: 1st, to dispel the arsenic and sulphur (present in the ore in

* For description of Figs. 10 to 18, which give details of Fig. 9, see Explanation of the Plates.

† Sufficiently rich to be worth saving.

the form of pyrites) by sublimation; 2nd, to convert the metallic bases (iron, copper, &c.) of the pyritous and other minerals (it is desirable to get rid of) into oxides, that are specifically lighter than their original derivative compounds, and can consequently easily be removed by subsequent washing; 3rd, to form compounds of bismuth that are soluble when lixiviated with hydrochloric acid (HCl), but are not sufficiently light to be removed in dressing.

CHAPTER IV.

ROASTING.

THE roasting-furnace in which this is done, Figs. 21 and 22, is of the reverberatory type—Germ. Flammofen—with the addition of flues (*d*), for the condensation of volatile products (principally arsenious oxide) in chambers, Fig. 23, connected with it.

The hearth is 14 to 20 feet long and 5 to 8 feet wide, with the fire-place at the further end from the working doors, (*a a'*) that are double, exposing, when open, the entire breadth of the oven.

Its bridge (*b*) is 6 inches high, and 1 ft. to 18 in. below the crown of the arch that forms the roof, which, as it is flat on top, is used as a drying-floor (*c*).

A noteworthy feature is an iron roller that is set in the doorway (*a*), just above the sill, so as to reduce the labour of rabbling the charge, as the heavy tool can be run backwards and forwards upon it with much greater ease than over a mere bar.

The process is carried out as follows :—1200 to 1400 lbs. of concentrates, when thoroughly dried, are introduced through the opening (*f*) in the roof, and, after being evenly spread out upon the hearth, the furnace is brought to a proper temperature, whilst "the roast" is constantly rabbled, in order, as far as possible, to prevent it from sintering, and to expose it uniformly to the heat, continuing this treatment until it ceases to give off fumes, when the temperature is

raised, and a certain quantity of charcoal is introduced and thoroughly mixed with the ore, in order to further assist in reducing the sulphates and arseniates (that are formed at the beginning of the operation) to basic salts.

The charge is drawn usually at the end of 6 to 24 hours, depending on the amount of arsenic present, and during the final stage of its treatment (described in the last paragraph) is only occasionally rabbled, taking also special care that the door of the flues leading to the condensing-chambers, as well as the outer double-doors (*a'*) of the furnace, are kept carefully shut, whilst the inner ones (*a*) are open, in order that any "dust" carried forward by the draught, as not unfrequently happens, owing to the fine state of division of the particles of charcoal, may go up the chimney (*g*) instead of into the chambers, for if it did so it would render the arsenic unfit for sale.

Sometimes when sulphur is present a sulphate is produced,* which is soluble in hydrochloric acid, and frequently causes a loss in the subsequent dressing that, in some Cornish works,† amounts to as much as 1½ per cent. of the tin in the concentrates (tin witts).

* Ordinarily the tin is but slightly decomposed or altered in "roasting."
† Kerl Metal Hültenkunde.

CHAPTER V.

ARSENIC AND ITS TREATMENT.

THE arsenious oxide—Germ. "Gift-mehl"—As_2O_3, caught in "the chambers" Fig. 23, is generally more or less grey and dirty looking, but when it is in sufficient quantity in the ore to be worth saving specially, a better and hence a whiter quality can be produced by commencing with and maintaining a higher temperature in roasting from the outset. In doing so, there is, however, a greater tendency for the ore to clot, which, should it so happen, must be checked by rabbling it more frequently, and lowering the temperature until the charge just glows, and gradually becomes slack.

The chambers, Fig. 23, are of the zig-zag design usually met with (in Germany) when the object is to collect crude arsenic, and might, I think, be slightly improved upon.

Fig. 24 shows an alteration I proposed some years ago, which, whilst tending equally to delay the fume-current, by placing the same impediments in its course, gives a greater cooling-surface than is presented by an equal length of chamber of the common form, or than can be obtained in any other way, for the expenditure of a given amount of masonry and material, economising, therefore, both space and cost.

The arsenic often forms very fine crystals that cling to the sides and roofs of the chambers, and it is cleaned out and removed from them every 3 to 6 weeks, preparatory to being refined, and prepared for commercial purposes, by convert-

ing it into white-glass, in iron vessels, 2 ft. 5 in. high and 1 ft. 10 in. in diameter, that each hold 2½ cwt. of sublimate.

The operation is carried out at Altenberg, as far as I can learn, in much the same manner as at Swansea, South Wales, where the plant employed for a similar purpose consists of four cast-iron vessels or basins (A), Fig. 25, 24 inches deep and 2 inches thick, supported by flanges (*a*), resting upon an iron plate (*b*), set on a seat of masonry (E) 20 inches high, that raises them above a grate (F), opening on the outside of the building the process is conducted in.

The rims of the vessels are flush with the surface of the bed (*b*), as the edge of the openings in it are bevelled out to receive the flanges, whilst due allowance is made for expansion, by cutting the plate through at (*e*) the back of all of them.

Above each basin there are two flanged cast-iron cylinders (B and C), each 2 feet high and 2 inches thick, set one over the other; the lower one having the same bore at the base as the diameter of the vessel (A) underneath, but tapering towards the top, like the upper one (with which it corresponds), 1 inch in its length. A conical cap (D), 18 inches high, rests on top of the uppermost cylinder, and is provided with a flange (*f*) cast round its apex, forming a seat for a 2-inch pipe (*h*), that carries off the surplus fumes of arsenic which are produced, and that go back to the chambers during the progress of the process; whilst there is a second opening (*k*), 1 inch in diameter, on the side of the cap, usually kept closed with an iron plug, which is used to control the progress of the operation by inserting an iron test-rod.

The lower cylinders can be wedged to the plate on which they rest, by means of the iron stirrups and angle wedges (S V), and the cylinders and caps may, if necessary, be secured by screw-clamps fixed to the flanges, so as to

ensure their remaining gas-tight; but their weight alone is usually sufficient when the joints are properly red-leaded.*

The separate parts have to be raised by means of overhead running tackle.

The vessels are charged by introducing about 300 lbs. of arsenious acid (As_2O_3) into each. The caps are then put on, the necessary connections made, and a steady fire maintained directly underneath them for 4 to 8 hours, entailing a consumption of about 2½ cwt. of coal per kettle.

Success depends on regulating the temperature, so that it is neither too low nor too high, as in the one case either a cloudy poor quality of glass will be produced, or the arsenic will sublime and condense in a flocculent state in the flues and upper part of the cylinders; whilst in the other, owing to the fumes ascending too rapidly (vertically, instead of circling *gently* upwards as they ought to do), they are driven out of the cylinders before they have time to settle on the sides of the drums, where they melt to a clear white vitreous substance, the so-called arsenic glass, if the heat is kept properly, between the extremes to be avoided.

The temperature required to effect sublimation is somewhat higher than would under ordinary circumstances be necessary; for as the process is conducted in a closed space, the fume is in consequence under a certain amount of pressure, which delays its escape, and has the effect of forwarding the formation, besides, it is said, improving the quality of the glass, that collects in a sort of scale or lining, some inches in thickness, all around the inside of the drums and caps.

The right point is reached, when cold water dashed with the hand or a brush against the outside of the upper drum,

* Eisenkitt, a cement of oxide of iron, is used in Germany for this purpose.

gradually disappears like breath off a cold surface; whilst on the lower one it ought to fizz, and evaporate with ebullition of steam.

The operation is ended, when an iron test-rod, introduced through the hole (*k*), no longer shows a white coating of arsenic condensed upon it; and next day, when the vessels have thoroughly cooled, they are taken to pieces, to remove the glass, and prepare them for making a further quantity.

Besides the unvitrified portion of the charge that returns in the form of fume to the "chambers" when the arsenic is not first thoroughly refined, a residue, partly earthy, partly metallic, often forms a pulverulent deposit at the bottom of the vessels, that is thrown away unless of sufficient value to be returned to the roasting oven.

The "glass" has to be hermetically sealed in barrels or cans, for greater safety, and to keep it from exposure to air, as it would otherwise become after a certain time opaque, which renders it unmarketable.

Arsenic is specially used for the following purposes:—

(*a*) In making paints (Scheeles green, Schweinfurt green, and King's yellow), and for fireworks.

(*b*) In paper-printing, dye, and bleaching-works.

(*c*) In the production of arseniate of soda, and other chemicals and drugs, as well as aniline colours.

(*d*) In the manufacture of flint glass.

(*e*) To harden plaster casts.

(*f*) For vermin and insect powders, and to prevent smut in grain.

(*g*) In Fowler's solution (used for washing sheep).

(*h*) To harden shot, and give the grains a spherical form.

(*k*) Alloyed with copper, it forms a white metal, often employed for clock, compass, and aneroid dials, &c.

CHAPTER VI.

FINAL CONCENTRATION.

THE ore, after being roasted, is sieved to get rid of lumps (that must be re-stamped) before it is returned to the dressing-house, where it is again run through the "tye" (P), Figs. 4 and 19, so as to remove the altered compounds of sulphur, arsenic, and iron, which being now decomposed and specifically lighter than the tin, as already said, are easily washed out of it, colouring the water a blood-red, and leaving clean ore behind, that goes for final concentration to the inclined table—Germ. "Glauchheerd"; Corn. nicking-buddle—(K), Fig. 4, constructed as shown in Fig. 20, that yields concentrates, in much the same way as in the earlier washing preceding the roasting, that I must for a moment revert to, as I before stated I should do.

The first step in this operation, is to form a sufficient quantity of ore (enough to cover the working surface, when spread out in a thin sheet) into a sort of dam near the top of the table, over which water is then allowed to flow, until the heap is gradually worked away—Germ. "eingeschlämmt"—with the assistance of a scraper, Fig. 26, called an "Einschlamm-kiste," that is used to spread and move the material about before subjecting it to be brushed ("gekehrt") with a broom, Fig. 27, made of pine boughs.

The method of doing this is by sweeping from side to side in a semicircular fashion against the descending current, in

such a way as to delay the heavier, i. e. richer particles, that would be otherwise carried away by the stream, which moves without floating the lighter grains of waste downwards, as they are gradually swept off the bed, leaving behind a concentrated product, called "Steinwage," that is collected in a wooden tray, the "Stein-trog" * (A), Fig. 28, and re-worked.

The subsequent stage of washing, called cleaning—Germ. "die reinigung"—differs slightly from the process just described, inasmuch as the ore is separated from the waste still mixed with it, by brushing it out in narrow strips, which consist of the enriched portions known as "Guter-stein," that are removed separately with a flat wooden shovel (Einfangschaufel), Fig. 29, whilst a board, placed at the foot of the table, dams back the water into a sort of "pool," where some of the *comparatively rich* ore, "Gefälle," that would otherwise get mixed with the more or less rich tailings, i. e. inferior concentrates, escaping at the end, settles, and is caught.

These settlings, "Gefälle," give when re-worked (*a*) what is called "poorer ore" — Germ. "Geringer-stein" — (*b*) a poorer class of settlings, or 2nd "Gefälle," and (*c*) black-tailings or "Schwärze," that are entrapped in a box sunk in the floor, at the end of the table, and are so termed from the colour imparted to them by the scraps of battery-iron, and iron-glance they contain.

This "Schwärze," after weathering in the open air for a year to oxidise the iron, is roasted, mixed with poor zwitter, and then stamped and washed as before, giving concentrates known as black-ore, or "Schwärz-stein."

Lastly, the poorer settlings, or 2nd "Gefälle," are accumulated, left to weather for four or five years, mixed with the 3rd "Gefälle" obtained by re-working the inferior con-

* Much the same as a "Sicher-trog."

centrates from the "Steinwage," and re-washed, yielding the last trace of mineral that can be profitably got out, the so-called tailings-ore, "Abgangs-stein."

The bed of the tables is given an inclination of 2 to 7½ degrees, according to the fineness of the ore, which is worked in lots of 12 to 25 lbs., depending on its degree of concentration, using 3 to 5 gallons of water, and taking half an hour to an hour and a half to concentrate and clean.

CHAPTER VII.

EXTRACTION OF BISMUTH.

THE concentrates coming from the inclined-table, when they contain bismuth, are collected and placed in a leaching tub (A), Fig. 30, 18 inches high, and 3 feet in diameter, provided with a tap at the bottom to draw off the liquor, in which they are leached in quantities of 7 to 8 cwt., using 4 gallons of raw hydrochloric acid, and frequently agitating them during the three days "the leach" takes to complete. The next step is to draw off the liquor, which is conducted by a gutter (*a*), Fig. 31, to the distributing trough (A), and thence to the other trays (B B B), each holding about 5 gallons of the solution.

The trays are then filled up with water, and are allowed to stand quiet for at least a day, until the chloride of bismuth, precipitated by the addition of the water, has settled, when the superfluous liquid is tapped off, and the salt, having been thoroughly washed to remove any trace of acid, is dried and sold, or reduced to metallic bismuth, by smelting with lime and charcoal-powder in plumbago crucibles in the furnace, Fig. 32, to which the skimming-ladle, Fig. 33, and mould, Fig. 34, as well as the charging-scoop, Fig. 35, belong.

The tendency that bismuth has to crystallise is very remarkable; forming, as it does, curious step-like aggregations of crystals, which are so to speak one within the other, and are obtained by allowing a solid crust to form on the

top of a ladleful of molten metal, piercing two or three holes through it, and pouring off what remains beneath.

Crystals of large size are an indication of purity, whilst the presence of lead will prevent crystallisation altogether.

The metal is melted without any further addition of flux a second time, before being finally cast in ingots. It is used in medicine, in making type, thermo-electric piles, solder, stereotype-plates, mosaic gold, i. e. equal parts of bismuth, tin, and mercury; fusible-metal, for boiler safety-plugs; gun-metal, bell-metal, pewter, bronze, speculum-metal, Britannia-metal, and for printing textile fabrics.

The mines of the Erzgebirge are amongst the chief producers of bismuth, as in 1879 and 1880 they yielded 73 tons 1200 lbs. and 72 tons 1900 lbs. respectively, valued at 18,627*l.* 3*s.* 11*d.*, equal to $90,648, and 17,507*l.* 16*s.* 3*d.*, equal to $85,210, out of which, during the latter year, 1868 lbs., worth 647*l.* 8*s.* 7*d.*, equal to $3151, came from the Altenberg district.

The ore remaining in the tubs after leaching is removed to the "tye," and washed with 4 gallons of acid diluted with 90 gallons of water, so as to dissolve out any bismuth still left in it; and then, having been passed once again over the inclined-table to get rid of any trace of acid remaining, is ready to go to the smelter, eight-tenths of the impurities it originally contained having been removed.

CHAPTER VIII.

SMELTING.

THE concentrates—Corn. "black-tin"—which average 50 to 60 per cent. of tin when they leave the dressing-house, are dried and sent to the metallurgical-works — Germ. "Hütte"—to be smelted.

The "blast furnace"—Germ. "Schmelzofen"—in which this is done, represented in Fig. 36, is built of stone, with a hearth (*a*) formed out of a block of granite, or felsite-porphyry, that has a fall of 4 inches towards the crucible or basin (*b*) lying outside of the breast or curtain (*c*), made of brick.

The crucible—Germ. "Vortiegel"—(*b*) is cut or moulded out of the fore-hearth—Germ. "Vorherd"—(*d*) composed of brasque.* A block of stone (*f*), as well as an iron breast-plate (*g*) set in front, keeping it in place; "whilst a canal" (*h*) underneath connects it with an iron bowl—Germ. Stechherd—(*k*) at a lower level, which can be warmed by means of the fireplace (*l*) below it.

The blast is supplied through a pair of twyers set in the opening (*m*), at the same inclination as the hearth-stone, which is not luted over in any way, and is about 4 inches below them.

The tap-hole in front, cut out of clay, is 4 inches high, 1½ inch wide at top, and 2 inches wide at the bottom;

* A cement of clay and coal-dust, composed, in this case, of rather more of the former than of the latter ingredient.

and must be a little above the "Vortiegel," as the flames issuing from the opening might otherwise oxidise the metal in the bath.

In those parts of the furnace where the heat is greatest a lining of felsite-porphyry, free from quartz, should be used, as the presence of silica, either in gneiss or porphyry, makes these rocks liable to fuse.

The area of the furnace, which it will be noticed is comparatively small in the neighbourhood of the twyers, and is contracted gradually towards the bottom, is so designed in order to concentrate the heat in the lower portion of the shaft, and to avoid "dead centres"; whilst at the same time the larger section, up above the zone of fusion, helps to diminish the tendency that the draught has to carry off dust.

The batter of the back wall prevents the charge settling too fast, and tends to bring it properly in front of the twyers.

The height of the shaft may vary between 8 and 10 feet, and is determined by the capacity required of the furnace, and the amount of iron in the ore; as a high shaft, whilst it shortens the length of the campaigns, induces the formation of "bears."

During a campaign that lasts usually three to four days, about 3000 to 3600 lbs. of ore, i. e. concentrates, 750 to 1500 lbs. of slag, 15 to 30 lbs. of stamped and washed residues and alloys, such as "Ofen-bruche" and "sows," together with 153 to 184 bushels of pine charcoal,* are put through daily.

The poorer slags from this first operation, which is called ore-smelting—Germ. Erz-schmelzen—are mixed with

* Pine charcoal averages 28 lbs. per cubic foot, hence a bushel weighs about 35 lbs. Approximately 1 $\frac{9}{10}$ths of a ton of charcoal is required to reduce one ton of ore.

fresh ore, and re-smelted in the next campaign; whilst the richer ones are mixed with rather more charcoal than is required in ore-smelting, and are worked separately in the same furnace towards the end of the run, an operation known as altering the slag (Das schlacken verändern). When a furnace is set in blast, after the fore-hearth has been warmed for some hours, about 200 lbs. of ore is mixed with a quarter its weight of slag on the charging floor at the back, and is shovelled through the door in the upper part of the shaft on the top of the charcoal, with which the furnace is first filled, to start it going. From this period onwards to the end of the campaign, as the charge is gradually but constantly sinking, about 60 lbs. of fresh ore is thrown in every 15 to 20 minutes, with sufficient charcoal to keep the furnace always almost full.

The charcoal is in lumps, that should not be larger than 1 inch × 1¾ inches, and is moistened, by being immersed in a water-tank, 4 ft. 6 in. square, at the back of the furnace, before the charge is made up, in order to make the finer particles of ore adhere to it, and so still further reduce the amount of dust carried off by the draught; but, as even by this means the escape of a certain quantity cannot be altogether avoided, a system of "dust chambers" in connection with the furnace is necessary as well.

The top of the shaft is kept dark, and the short nose that is at first formed on "the twyers" afterwards disappears entirely, a slight loss being incurred either way, as, when the strength of the blast is uneven, oxidised metal is blown out of the tap-hole, where otherwise it goes up the shaft.

Shaft-furnaces as a class are generally inferior for smelting tin to the reverberatories used in England, as they require more fuel, oxidise a larger amount of tin, and are less under control; but with refractory, especially arsenical ores, they yield a purer product, owing to the increased

facilities which impurities have to be carried off by sublimation, or for assimilating with the slag that is produced in greater quantity.

The particular type of furnace used at Altenberg is known as a "Spur" or "Gutter-ofen," because of its discharging continuously from the opening in front into the "crucible" outside, as is sometimes arranged through a covered canal. It has several advantages over other kinds of shaft furnace used for tin smelting, because, although the separation effected in the first instance is not so perfect as it might be, and the slags are in consequence exceptionally rich in metal; owing to the oxidisability of the tin, this disadvantage is more than counterbalanced, by the saving that results through removing it as quickly as possible out of reach of the blast.

It also economises fuel; but that advantage is partly neutralised, by the constant abstraction of heat going on from the interior, as the slag, metal, and other molten matter runs from the furnace; whilst, owing to the reducing action of the gases in the shaft, when oxidised ores of iron are present, there is a very annoying tendency to form "sows," liable to contain, in addition to iron, small amounts of arsenic, bismuth, wolfram, and copper.

Whilst the campaign lasts, the temperature must be kept at a bright yellow heat; for if it were allowed to increase to white, when seen through the "tap-hole," a great loss of tin would be occasioned by sublimation. The molten material too, flowing from the furnace, should appear of a reddish colour, and be attended by an emanation of light-blue vapour, which, by becoming dark and thick, indicates that a higher temperature is required.

The slag as it collects uppermost in the crucible is skimmed off, and thrown into the water-tank (*p*) at the side;

the exposed surface of the tin being at once covered with charcoal, to protect it from the air.

The time that the basin, i. e. vortiegel, takes to fill, depends on the richness of the ore, and the facility with which it smelts. When a run is made on rich ore, it fills quickly, and sometimes gets too hot. In that case, in order to reduce the tin to the necessary temperature for liquation, it is ladled into the bowl, i. e. stech-herd, below; where an alloy known as "Härtlinge" "Hartbruch," that also occasionally forms on the hearth or in the "Vorherd," separates out (if much iron is present), as the metal becomes *comparatively* cool.

Since it has become the custom, however, to treat the concentrates with acid, to extract the "bismuth," whatever alloy is formed is much poorer in iron than it used to be, and, under the name of "Ofenbrüche," is stamped, washed, and returned to the furnace the next time it is in blast upon ore.

In ore-smelting (erz-schmelzen) the furnace-tin—Germ. Werkzinn—that is left after the slag has been removed from the basin, when sufficient has collected, is ladled out, and liquated on a grooved iron refining-plate (*s*) at the side, called a "Pauschherd," which is covered with clay, and, after being first warmed, has a layer of glowing charcoal spread over it.

This Pauschherd is 3 ft. 7 in. in length, 2 ft. 3½ in. in breadth, and 1½ inches thick, and is inclined at an angle of 35 degrees. The molten metal is poured from some height above it, on to its upper end, and percolating through the charcoal, in which the less fusible substances contaminating it remain behind, collects in the iron reservoir near its foot.

At the end of this process, which is repeated several times, the charcoal is swept into a heap, and pounded with wooden mallets until all the tin has been got out of it, in the shape of "shot" and "dross," known by the various names

of "Zinn-körner," "Zinn-pausche," and "Saiger-dörner," that is treated in the operation to be presently spoken of known as "Schlackentreiben," whilst the residue is thrown away.

The "Stechherd" is principally required at the end of the "ore smelting"—i. e. "Erzschmelzen," when the "Schlacken-verändern" process begins, as the alloy of "Hartbruche" or "Ofenbruche," already referred to, that is then more liable to form, is left behind in the "Vortiegel," by allowing the molten metal to run down into it through the connecting canal.

The slags, which are essentially ferrous silicates of a greyish or brownish black colour, should fly to pieces readily when they are thrown into water, and they usually contain beads and shot of metallic tin, as well as fragments of cassiterite.

According to Richter's revised edition of Plattner, their composition would be on the average as follows:—

TABLE SHOWING THE AVERAGE COMPOSITION OF VARIOUS TIN SLAGS.

No.	From the Altenberg furnaces.	SiO_2 %	FeO %	SnO %	CaO %	MgO %	Al_2O_3 %	As_2O_3 %	Sn %	C %
1	Obtained in ore smelting ...	20·05	30·15	25·12	1·10	1·23	5·00	3·90	11·22	1·47
2	Obtained in schlackenverändern	32·00	42·51	9·01	1·35	1·75	8.10	4·00	—	—
3	Obtained in schlackentreiben	33·10	44·05	7·50	1·47	1·89	7·33	2·95	—	—

Of the above, the first slag was rich in tin, the third good and glassy.

The slags resulting from smelting those first obtained over again in the furnace, Fig. 36, "Das schlackenverändern," already described, are collected and treated separately at the end of a campaign by a process known as "refining the slag," "Das schlacken treiben," conducted in a slightly different furnace, called a slag-refining furnace, Germ.—Schlacken treibofen (Fig. 37).

The chief structural differences of this latter are, that the shaft is not more than 6 feet high, and is broader and wider than that of the other, so as to minimise the tendency the iron has to become reduced out of the slag; but since, in spite of this, "bears" will form more or less, the hearth as well as the fore-hearth is covered with brasque of lighter * quality than is used in the larger furnace, in order to prevent the slag sticking to it.

The shaft may also be built of less fireproof material than could be employed in the construction of the furnace, Fig. 36, as the campaigns only last a short time.

The tap-hole, too, is of greater size, 8½ inches by 2¾ inches, whilst the "twyer-nozzles" are 4¼ inches above the hearth.

In "slag refining," after properly warming and setting the oven in blast, a couple of trays,† one on each side of the shaft, are filled with slag, which is thrown in with about two-and-a-half times as much charcoal on top, in addition to a certain quantity of liquation dross or "Saigerdörner," chamber-dust—Germ. "Flugstaub,"—&c., which helps to make the charge flow properly, and prevents its becoming too viscous. The blast, too, is served at an increased pressure. When there are yellow streaks visible in the slag running from the notch or "eye,"—Germ. "Auge"—the temperature is too low, and consequently it does not run freely.

The impure slags that accumulate and cling around the "eye" are returned to the furnace, whilst the cleaner and more siliceous ones are taken out of the crucible in front, chilled in water, stamped, and washed, and the grains and slimes resulting are subsequently put through the same process again.

* The proportion of coal-dust used in its composition is increased.

† The trays here mentioned, are each equivalent to a measure called an "eimer," 27 in. long, 16 in. high, and 8 in. wide, that has consequently a capacity = 3456 cub. inches.

The slag-refining furnace when in blast smelts the slags from three campaigns on raw ore.

The metal obtained from it, called slag-tin — Germ. Schlackenzinn—is ladled out of the Sump or "Vorherd" and liquated, yielding a marketable though more impure tin than that got from the earlier treatment in ore-smelting. See analysis No. 2, p. 41.

For every 5 tons of black-tin reduced, about 1½ to 2 tons of slag is produced, which is re-worked as already described, whilst the quantity of metal obtained varies between 300 and 400 lbs.

In washing rich tin slags, if care is not taken, the metallic shot, that are the most valuable portion, are liable to be carried away, as they are apt to be stamped into very thin plates, which have a tendency to float.

The Härtlinge obtained during the Schlackentreiben is so rich in iron (often containing 50 per cent.) that it has to be broken into lumps and roasted in "open heaps" before being put back again, with dross "Geschur," sweepings, "Gekratz," &c.

To cast the tin, which when refined is known by the name of white-metal, it is necessary that it should be of the proper temperature, indicated by the surface of the bath being bright and glassy, and of a slightly bluish tint.

If the metal is too hot when poured, the outside of the bars assume rainbow tints (chiefly blue), which show that the tin is red-short; if, on the contrary, it is poured when its temperature is too low, it becomes cold-short, losing its hardness, lustre, and ductility, and its surface then appears dull and reddish coloured.

In order to avoid these evils, small quantities are poured for trial, from time to time, upon a copper plate, and should the bath be too hot, the test-pieces, when chilled, are thrown back into it, until the metal is reduced to the

proper temperature; whilst, if too cold, the basin must be kept covered with glowing charcoal until a fresh quantity of metal is run off the liquating-plate, giving an accession of heat, that allows of casting the tin into blocks or plates.

The Saxon tin is not inferior in quality to the best English kinds, and since it has become the custom to treat the ore with acid, it contains only about 1 per cent. of bismuth, though before it is refined it is contaminated with more or less iron, copper, arsenic, antimony, molybdenum, wolfram, &c., that have to be got rid of, either by liquating, as we have seen is the practice pursued at Altenberg, or else by "poling," the more ordinary method in England. The latter system, if in some respects superior to liquation, requires, however, more fuel and time, and from trials that have been made does not appear suitable to the German ores containing arsenic, traces of which always remain.

The nature and amount of gangue exercises an important influence on tin-smelting in shaft furnaces, as silica, which is most abundant in the volcanic rocks, tends to form a viscous slag, containing globules of metal, whilst, if iron or lime is used in any quantity as a flux to correct this, there is danger of slagging any metal that may have become oxidised.

The difficulties lying in the way of the smelter are:—

1st. The oxidisability of the tin, at the high temperature required for its proper reduction; the air blast further adding to this loss by actually driving out of the furnace some of the oxides that are formed.

2nd. The presence of iron, bismuth, antimony, &c., that are more easily reduced than the tin, and either impurify it, or, by forming "bears" and other impediments, interfere with the action of the charge.

3rd. The ready tendency of oxide of tin to slag and form a base with fluxes in the presence of iron and other

metals, from which it can only be separated at a high temperature in a reducing atmosphere, with considerable difficulty and loss, as already shown.

By washing, roasting, and treatment with acid, the impurities that cause trouble are, of course, partly removed before the ore comes into the hands of the smelter, and the evils spoken of under the second and third headings are consequently minimised, but with wolfram for instance, which, if in large quantity, requires a special process, such as Oxland's, to remove it, this cannot be done entirely, and, even after refining, usually small quantities of foreign elements are more or less present in the tin, deteriorating its quality.

TABLE* SHOWING THE QUALITY OF VARIOUS KINDS OF TIN.

No.		Sn	Fe	Cu	Bi	As	Residue.	Remarks.
1	Furnace-tin, Werkzinn, Altenberg	99·60	0·06	—	—	0·05	—	
2	Slag tin, Abgangszinn, Altenberg	97·83	0·11	Trace.	—	Trace.	1·00	Traces of Wo and Mn.
3	Slag tin, refined, Altenberg	—	0·09	—	1·40	—	—	
4	Best refined tin, Altenberg...	99·90	—	—	0·10	—	—	
5	Best refined tin, England	99·76	Trace.	0·24	—	—	—	

* Compiled from analyses given in Kerl's 'Hüttenkunde.'

A crystalline texture and deep depression on top of the bar is said to show want of purity, and the tin when chilled should, properly speaking, have a smooth, clean, white, and lustrous surface.

Iron, of which there is usually a trace, in tin of even the best quality, injures its colour and lustre more or less when it exceeds ½ per cent., and 1 per cent. is sufficient to make it dark-short, i. e. brittle and dull, besides causing rust spots

to appear on its surface when exposed a long time to the air.

Copper in small quantity does no harm, but above 1 per cent. it makes the tin harder and less malleable, whilst a larger amount increases its brittleness, deprives it of lustre, and when it exceeds 11 per cent. trebles its hardness, and gives it a perceptible tint. Its presence is very desirable, however, in metal used for making tinfoil for looking-glasses, as it prevents the mercury attacking the foil too readily.

Bismuth and antimony give it a crystalline structure, and, when over $\frac{1}{2}$ per cent. of either is present, injure its malleability, even more than iron; the former metal also renders it more fusible.

Lead makes it harder, and imparts a greenish tint to it.

Arsenic, even if there is only $\frac{1}{2}$ per cent., notably influences its malleability as well as its colour and lustre, and when it contains above 1 per cent. the tin becomes lighter, and is covered with white spots, making it in time turn dull, darker, dirtier-looking, and spotted.

Zinc renders it whiter, but harder and more brittle.

Wolfram and molybdenum in large quantity similarly affect it, though the tungstic acid in the former mineral is partly removed in smelting, by its re-combining with metallic iron, or attacking any of that metal there is in the slag.

English common tin contains $\frac{1}{5}$ per cent. of iron, and copper up to 1 per cent., but, when refined, any arsenic, lead, or copper that may have been present is removed, and the iron is reduced to $\frac{1}{10}$ per cent.

The loss in smelting in Saxony is from 13 to 15 per cent., of which 8 to 9 per cent. is incurred through volatilization, and the rest by slagging.

Roughly speaking, Saxony produces annually about one-thirtieth of the amount of tin that is obtained from Cornwall.

Cheap wages and careful dressing enable the Altenberg tin to compete with that from the Cornish mines, and though the method of dressing the ores of this district may possibly at first sight appear insufficiently automatic, it should be recollected that a large quantity of stamp-stuff is required to obtain an appreciable amount of concentrates, whilst the loss in tailings, as well as the quantity of water required for washing, has to be reduced to a minimum, conditions under which it is probable, that neither a buddle, nor any other concentrator, can, with equal regard to economy, surpass the "Stossheerd" in efficiency, when it is properly handled, and used for the special kind of work adapted to it, i. e. working *fine*-sands and slimes.

Of course, in newer works, iron tables of the Salzburger pattern might be substituted with great advantage for the wooden ones of the old type, like those at present in use, whilst continuous percussion-frames—Germ. Rittingerschen Stossheerds—would, at any rate, advantageously replace the nicking-buddle; and pointed-boxes—Germ. Spitzkastens—the "classifiers" that are still employed.

It is also more than likely that a great saving could be effected in roasting, by adopting revolving-cylinders in place of the ovens, which may yet be seen in operation in this locality.

CHAPTER IX.

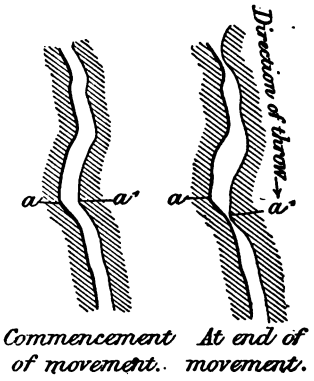
ZINNWALD.

INTRODUCTION AND GEOLOGY.

THE district of Zinnwald, which next claims description, lies about six miles south-east of Altenberg, on the actual border line between Germany and Bohemia.

The tin mines on the Saxon side of the frontier are here located in a series of rocks forming an immense truncated

FIG. 38.



elliptical-dome of granite and greissen, Fig. 38, the top of which has been removed by erosion, and measures 4460 feet along the major, and 1574 feet across the minor

axis of its outcrop; the central core being overlain on all sides by felsite-porphyry.

The granite is mostly fine grained, and encloses patches and masses of greissen of all sizes, up to 330 feet in diameter, which, generally speaking, pass gradually into the enclosing rock, though instances are sometimes met with where the demarcation is sharply defined.

The greissen itself, a granular crystalline combination of quartz and white lithia-mica, as in the case of the Altenberg zwitter, contains here and there pockets of unaltered granite, that do not show any trace of ore, whilst the entire formation is intersected and subdivided by a series of true fissure veins (incorrectly termed "beds"—Germ. Flötze—by the miners) lying under, and more or less parallel to, one another, and dividing the central granitic mass into a number of concentric bell-shaped scales, like the inside of an onion.

These "beds" so-called, of which sixteen are known, are the most important class of ore deposits the formation contains, and dip gently towards all points * of the compass. They are from 4 inches to 3 feet wide, and lie at varying distances apart, from 12 feet up to 120 feet; the space between them generally increasing as they gain in depth. They are principally filled with wolfram, cassiterite, quartz, and lithia-mica, though galena, hematite, zinc-blende, tourmaline, apatite, heavy spar, and other minerals are also sometimes present, and where there happens to be "a druse," specimens beautifully crystallised may frequently be met with.

In most instances there is no sharp distinction between the contents of the fissures and the country-rock that borders upon them; and whilst in some cases the felspar in the granite that originally formed the walls has been decomposed into kaolin, at other times a horn-stone has been

* Hence the elliptical shape of the mass.

produced by an exactly opposite process of silicification. Further, it is remarkable that though the greissen contains tin, the granitic pockets enclosed in it are entirely free from all traces of ore, giving support to the idea that where portions of the formation escaped the metamorphic agencies by which the surrounding stone was altered, no deposition of mineral took place.

The second class of deposits, to which allusion has already been indirectly made, consists of a separate series of narrow lodes, that traverse the entire mass of granite, dipping at a steep angle of about 65°, and preserving a general course running north-east by south-west.

They are mostly barren, with merely a filling of sandy, decomposed granite, or greissen, more rarely cassiterite, wolfram, mica, fluorspar, and gangue, and often "fault" and "throw" the so-called beds (Flötze) several feet.

Their value lies in the marked enrichment that usually takes place along the lines of junction thus formed, and in consequence of the country rock in their neighbourhood having become highly impregnated with tin and wolfram, most probably through their influence.

Herr Müller calls attention to indications that exist which seem to point to a re-opening of these secondary fissures having occurred; but shows that, whether this movement took place after the first class of veins had been completely filled or not, their contents need not necessarily under any circumstances be of younger origin.

Apart from that question, however, the relative conductivity of the different kinds of stone of which the walls of the fissures were composed, the smoothness or unevenness of their surfaces, and the openness or otherwise, as well as the general shape of the clefts, have doubtless all been instrumental in determining where the mineral should be

* H. Müller, Berg. u. Hüttenm. Zeitung, 1865, p. 179.

deposited in greater or less abundance. The rougher portions of those rocks that were at the time of infilling the best conductors, or where, in other words, the most rapid abstraction of heat from the solutions circulating through them took place, being the most likely places for deposition; especially when a segregation of the ore and matrix in a crystallised state resulted from cooling and chemical change, rather than through the mechanical precipitation of material in suspension.

The sole objection that is sometimes raised to the theories of La Conte and Dana, with regard to the origin of ore-deposits in veins, viz. how fissures of the necessary magnitude were kept sufficiently long open to admit of the action that is supposed, seems to me a very absurd one. The result of two adjacent planes of indefinite extent, being separated by "faulting," must in any case have caused sufficient dislocation to bring the unevenness on the surface of one wall in juxtaposition to those on the other, as shown in the ideal illustrations, p. 44; not to mention the wedging of pieces of detritus of all sizes, which, even if mostly reduced to the size of gravel or sand, would still allow water or vapours to filter through the cleft, around the "horses" or larger fragments, and even in the less open parts.

CHAPTER X.

MINING.

THE principal mine of the Zinnwald district—the Vereinigt Zwitterfeld Fdgr—is worked by means of the Albert shaft, 72 feet deep, which has been sunk at the end of an adit, coming out at the foot of the hill, that has been run at an angle to the outcrop of the beds (Flötze) alluded to in the last chapter; these latter, owing to their slight dip, are each intersected by it in turn, saving the expense of driving through entirely dead ground, whilst affording the best means of exploring and working the deposits, which extend indefinitely on either side.

The system of development pursued, consists in driving cross-cuts from the adit, wherever it cuts through a bed, and then working out a large irregular chamber without pillars, of an area depending on the quality of the roof, and a height in some places corresponding with, in others rather more than, the thickness of the pay-zone.

The excavations thus formed, though of various sizes, are as may be supposed of comparatively uniform dimensions; and to avoid caves, when the roof shows signs of weakness, a short drift is at once driven up or down the plane of the bed, in any convenient direction, until it is sufficiently advanced to make it safe to commence another chamber, which in its turn is made to communicate with others beyond.

In most of the chambers the roof is very smooth and firm, and a constant tendency, noticeable more particularly on one side of the adit, can be observed, to push the face of the workings systematically forward up the dip-slope.

Geological sections of great interest may be met with in the workings; one, Fig. 39, that particularly drew my attention, is characteristic.

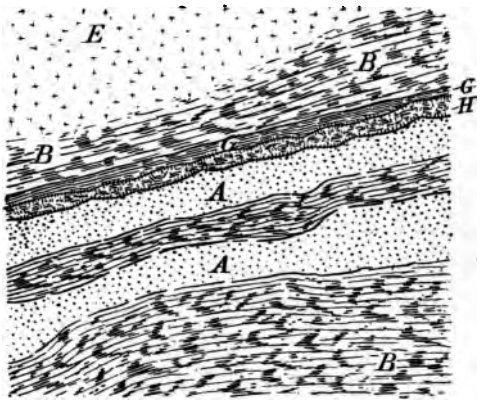


Fig. 39.

It shows admirably the general ribbon-structure of "the beds"; consisting, as may be seen, of streaks of "pay" (A A), alternating with parallel layers of barren vein-matter, or country rock: whilst underneath "the greissen" (B), that passes into granite (E) and forms the roof, there is a soft white decomposed layer of kaolin (G), separated from the filling of the vein by thick lenticular tufts of green mica (chlorite) (H) interbedded with very large and perfect crystals of wolfram and quartz, the latter mineral frequently occurring "capped."

The lodes, "Gangs," or Klufts, which belong to the second class of ore deposits, as already said, often produce,

a marked enrichment of the beds ("Flötze") along their line of junction with these latter; and dipping as they do almost perpendicularly, "winzes" are usually sunk at points along them, whenever it is necessary to form a connection between different beds, since by that means any existing intermediate pockets can be thoroughly explored.

CHAPTER XI.

TIN-DRESSING.

THE methods as well as the machinery employed to dress tin at Zinnwald may be dismissed in a few words.

The ore from the Zwitterfeld mine carries from two-fifths to four-fifths per cent. of tin, and is associated with little if any bismuth or molybdenum, whilst it is intermixed with an extraordinary amount of wolfram which it is the chief object to save; and as the output of *tin* from these works is comparatively limited, the system of dressing differs but slightly from that at Altenberg.

The first step is to sort "the pay" from "the waste" or "deads" at the working-faces, as the latter are used for walling and filling underground.

The ore is then raised to the surface, and goes to the "sorting-ground," where it is picked over by hand, broken or spalled to the proper size, and divided into two separate classes, 1st, tin-ore, and 2nd, wolfram-ore,* which can be easily done, owing to the mode of occurrence of the crystals of the latter mineral; each sort going to an entirely separate building for subsequent concentration.

The "Zinn-wäshe," or tin-dressing floors, have a plant of

* Through the kindness of Herr Bachmann, of Altenberg, I am able to state that *latterly* "wire sieves" have been employed to separate the coarse (Stuck-wolfram) from the finer grades of ore, as the former can be more profitably *jigged* (separately), than treated with what passes the sieves, which is stamped and washed as hereafter described.

stamps, 3 end-percussion tables, 1 tye, 1 inclined table, and 6 settling-tanks.

The battery-sands and slimes, coming from the stamps, are caught in the settling-tanks, which sort and partially concentrate them into three separate classes, coarse, medium, and fine; and permit anything that still floats, after passing through the boxes, to escape to catch-pits outside, where a gradual accumulation of "slimes" goes on.

Each grade of settlings is then worked separately, two or more times, on one of the end-percussion tables; and after having been washed in "the tye," the concentrates are finally cleaned on the inclined table (see Dressing-tree, Zinnwald) till they average 70 to 75 per cent. of tin.

They are now ready to be sent to "the smelter"* at Altenberg, where they are dealt with exactly in the same way as already detailed in the description of the process followed there.

* A term here applied to roasting and smelting-works.

CHAPTER XII.

TREATMENT OF WOLFRAM.

THE ore of the second class, consisting of wolfram in a siliceous gangue, associated with mica, goes to a building, Fig. 40, containing a plant of 8 stamps, space being reserved for 16 more * if needed later, 2 shaking-tables, 1 tye, 1 inclined-table, and 3 "four-compartment settling tanks," or boxes.

None of this machinery differs materially in size or construction from that at Altenberg, except as regards the dimensions of "the tanks" and "tye." The former (H), Fig. 40, being 23 ft. 5 in. long, is composed of four boxes measuring respectively 44 inches,† 42½ inches, 7 ft. 10 in., and 8 ft. 5 in. in length, 19½ inches in depth, and 26 inches in breadth; whilst the latter (P) is 16 ft. 10 in. long, 15 inches broad, 16 inches deep, and has an inclination of about 4°.

The larger and more valuable portion of the sands and slimes from the batteries are caught in the tanks, whilst the lighter and poorer ones settle in catch-pits outside, from which they are dug out and worked after they have accumulated for some weeks.

In this way four classes of settlings are obtained: the

* I understand that since I visited these works in 1879, the number of stamps *has* been increased; and hand-jigs, "hand Setz-maschinen," have been added for the reasons given in a previous foot-note.

† These first tanks (44 inches long) have *inclined* bottoms.

1st, coarse or rösche, comes from the first boxes; the 2nd, middle or zähe, from the second boxes; the 3rd, slime, consists of the combined settlings in the third and fourth sets of tanks; whilst the 4th is what collects in the pits.

Of these classes, the 1st and 2nd are worked separately on one of the percussion-tables, whilst the 3rd and 4th are washed on the other, each yielding headings, poor concentrates, and tailings by the first washing, which is repeated on the headings and middles, giving finally a considerable quantity of rich concentrates, with some sands, and tailings. See Zinnwald Dressing-tree.

Finally the rich concentrates are washed twice in the tye or "Schlämme graben," and once on the inclined-table; and the resulting product, after being put in a strong wooden tub* (K), Figs. 30 and 40, 27½ inches in diameter, and 28 inches deep, is beaten on the sides with clubs till the wolfram settles to the bottom, is taken out, dried, packed in iron-bound barrels holding 500 lbs. each, and sold for the manufacture of tungstate of soda, and tungstate of baryta, both extensively used in the arts, the former as a mordant in calico-printing and for rendering muslins uninflammable, the latter as a substitute for white-lead; whilst wolfram itself is employed in making Mushet-steel, which is excessively hard, and fetches a high price for making turning tools, and for various other purposes.

The Zinnwald works, according to Kerl, produced 5 tons of wolfram in 1860, that sold at about the present price, for 5fl. 1kr.,† equal to 8*s.* 10*d.*, or $2\frac{12}{}$ per centner ‡ (100 lbs.), whilst in 1879 the total production of the whole of Saxony was 27 tons 600 lbs., the Zwitterfeld mill contributing the entire quantity, an amount still further

* A kind of "tossing-tub." † A florin = a gulden = 39·12 cents.

‡ This represents 8*l.* 16*s.* 8*d.* per ton of 2000 lbs.

exceeded in 1880, when 32 tons 300 lbs. were produced, which realised 299*l.* 11*s.* 5*d.*

The table-sands also, being almost pure silica, form a marketable product, which amounted to about 254 tons in 1880, fetching 13*s.* 3*d.*, or $\$3\frac{18}{}$ per ton; whilst the tailings from "the tables," joining those coming from the settling tanks, go to catch-pits in the open air.

Fortunately a hand-sorting of the wolfram is possible in the first instance, otherwise the tin ore would have to be roasted either with common soda or sulphate,* to form a soluble tungstate of soda, as is done in Oxland's process, before subjecting it to a second washing, with a view to separate the one mineral from the other.

* Glauber's salt.

CHAPTER XIII.

ABERTHAM.

INTRODUCTION AND GEOLOGY.

THE district of Abertham, in Bohemia, where tin is said to have been discovered by a Cornish miner in the fifteenth century, is situated a few miles south-east of Johanngeorgenstadt, a town on the confines of Saxony.

The mines, with a description of which I shall conclude this subject, have been alternately in the hands of English and German proprietors, who have each in turn partly remodelled the work of their predecessors—a circumstance that sufficiently accounts for features which strike one at first-sight as being scarcely in strict accordance with the system one expects to find in a mine abroad.

The principal "ore deposits" are contained in a lode running through a granitic formation; but some mineral is also obtained from stockworks. The lode, which is 30 feet wide in places, and has an almost perpendicular dip, is intersected by several cross-courses. It has been opened up by a tunnel driven along it to meet a shaft, sunk 205 feet or 40 lachters from the surface, to the point where they join, and thence continued 51 feet or 10 lachters deeper.*

* This description, as well as that which follows, must be understood to apply to the condition of things existing about four years ago, and takes no account of any subsequent developments.

In parts of the workings one often finds the entire width of ledge-matter "gutted" to a considerable height and depth (a gunniss *) by working across the vein from side to side, and then "stoping" the ore out, either over-hand or under-hand, or by combining both systems, whilst in other places stopes may still be seen open that have been run up or down, sometimes both ways, to work out a pay-shoot, existing by the side of a level from which they start. The workmen employed in removing "the backs," standing, of course, on temporary wooden staging.

In the tunnel, flat track-iron, laid on wooden "stringers," is used in place of the iron T-rails commonly seen in the car-ways of most continental mines.

The ore, which probably will average 3 to 3½ per cent. of tin, is separated underground from waste, and carried for treatment to the neighbouring mill, Fig. 41.

* A gunnie is really only a Cornish term for a yard.

CHAPTER XIV.

ORE-DRESSING.

THE works, Fig. 41, are supplied with power by a water-wheel A, as well as by a small 4 horse-power engine (B), and contain, besides a plant of 8 stamps in two batteries, a set of pointed boxes—Germ. Spitz-kasten—4 end-percussion tables, 4 continuous side-percussion tables, and a complete series of settling-tanks as well as dissolving-vats and a steam-boiler.

The stamps (C C) weighing 500 lbs. each, and standing in two batteries of the Cornish type, Fig. 42, were formerly made with their stems and head all in one piece; but the arrangement was found to cause such frequent breakages and waste of iron, that their stems are now tapered and wedged on in the American way—a decided improvement on the old plan, though they are still unprovided with a separate shoe, as they ought to be.

They are run at sixty drops a minute, with a fall of 10 to 11 inches, and the screens (*a*, *a*, *a*, *a*), Fig. 42, made of wires crossing each other diagonally 2 millimeters apart, measure 6 inches by 11 inches, and are 4 inches above the bed; they are placed one at each end, as well as back and front of the coffer (A), Fig. 42, and are protected by iron bars (*b*, *b*, *b*), bolted on to wooden chocks (*c*, *c*, *c*).

The "battery-bed," 24 inches deep, is made of stamped "wacke" and in front of the coffers, which stand 3 to 4 feet apart, and are boarded in on top (D), Fig. 42, there is a sloping platform of tongued and grooved boards (D), Fig. 41, over which the battery slimes pass to a trough (E) that conducts them to the "pointed boxes" (F).

These boxes, four in number, which I shall distinguish as 1st, 2nd, 3rd, and 4th, are shaped like inverted pyramids; they measure respectively, though out of ordinary rule, 6 inches by 12 inches, 9 inches by 14 inches, 14 inches by 15 inches, and 18 inches by 20 inches, and are, it appears, designed to sort and separate 8 to 10 cubic feet of battery slimes per minute.

The first of the series, which is 8 inches deep, is supplied with clear water through a slit $\frac{1}{8}$ inch high and 12 inches broad, at the end of the gutter (H), Fig. 41, that opens immediately underneath the trough (E). The discharge from them being conducted through gutters (a', β') to a system of tanks (G G), Fig. 43, in two separate series (a' and β), where the best portion settles. That from the 1st and 2nd box being delivered to series a, whilst that from the 3rd and 4th goes to β.

Each series consists of two settling-tanks, with inclined bottoms—Germ. Gefälle—and seven ordinary tanks—Germ. Graben—forming nine compartments in all, of which the first six are side by side, and are emptied and filled alternately by opening or shutting the gates (a or a', b or b'), whilst the last three of both sets are arranged in a row, and are common to either the one side or the other that happens to be filling in the series to which they belong; their united overflow being finally discharged into the last and largest tank (K) of the whole system, that connects by means of the gutter (k), with settling-pits outside. The dimensions of the tanks are as follows :—

	Gefälle.	1st two pairs (Grabens.)	2nd two pairs (Grabens.)	3rd pair (Grabens.)	4th pair (Grabens.)	5th pair (Grabens.)	Last, Graben.
	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.	ft. in.
Length .	4 10½	4 7½	4 11	7 4½	7 6½	14 0	20 10
Breadth.	1 3	1 3	1 3	2 8	2 8	2 8	5 6
Depth ..	0 12½	0 12½	0 12½	0 12½	0 12½	0 13½	0 13½

The bottom of the Gefälle is inclined at an angle of 12°.

With this arrangement of tanks one gets two complete series of "settlings," and as those of *a* are naturally of greater *relative* sp. gr. than those of *β* (in consequence of the latter being throughout of finer grade), each lot is worked separately, though otherwise in exactly the same manner.

Each series of tank-products may further be divided for the sake of distinction into three classes—viz. Class I. Coarse-headings or Rösch-hauptel, *a* and *β*, consisting of settlings from the inclined-tanks; Class II. Middle products or Mittlere-graben, *a* and *β*, from the 1st and 2nd pairs of tanks; and Class III. Slimes or Schlämme, from the others that are worked each apart on end-percussion tables, see "Tree" of ore-dressing at Abertham—similar in pattern to the tables at Altenberg previously described.

Now, as any one who is at all acquainted with the German system of ore-dressing must be aware, in order to work these tables with any degree of success, it is essential that certain regulations, according to the class and character of the ore undergoing treatment, should be carefully attended to; but as the principles on which this depends and the means by which an intelligent workman judges of the need for as well as the nature of a requisite change and readjustment, are possibly not quite so well understood, I shall digress for a few moments from the direct subject of this paper to touch upon a matter that I think is one of considerable interest and importance.

The separation effected on "tables," whether they are of the percussive or stationary type, depends chiefly on the action that a shallow current of water exercises upon separate particles of ore of equal weight, but unequal bulk, which, in order to fulfil the last-named conditions,

must have been previously sorted in settling-tanks, pointed-boxes, or other classifying devices that separate according to differences in specific gravity.

For, to take the simpler case, it will be readily seen, that if two particles, one of quartz, the other of cassiterite, of *equal weight*, are placed side by side on a plane surface, like the bed of an ordinary table, in a shallow down-flowing stream of water, owing to the larger surface the former necessarily exposes to the action of the current, it will be kept constantly moving lower downwards, whilst the latter remains in its original position, providing that a proper inclination is given to the bed, so that the power of "gravity" and the current combined are neither too strong nor too weak when compared with the absolute weight and amount of friction opposed to them, as in the one case, both particles would be swept away together, whilst, in the other, neither of them would be moved at all.

There are other factors, however, which influence the question when the force of percussion is introduced as well.

First, there is the natural inclination which the heavier grains that are of sufficiently small size have to sink at once when the water momentarily deepens under the influence of the blow the table receives in falling back; and, in the second place, the direct action of the shock itself, that tends to settle the heavier minerals near the head of the bed, and even to make them work upwards against the current.

The necessity of giving the table a *proper* inclination, which is done by lengthening or shortening the chains at its *foot*, must manifestly, from what has just been said, be of the first importance, and it may be laid down as a general rule, that the lighter one ore is, as compared with another, the greater should the angle be that the bed makes with the horizontal, whilst the absolute weight of the mineral has

a yet greater influence than its specific gravity, a coarse grade of ore requiring more fall than a fine one.

To illustrate this, take for example a galena ore, and one carrying tin, both of the same grade: the former, being relatively the heaviest, would require the most inclination; but, if a coarser grade of the latter stuff had to be treated, the bed might have to be set at a still greater angle before proper work could be expected or done.

Again, we have to consider the effect on the working results, not only of the *amount* of water employed to beneficiate an ore under given conditions as well as the proportion of solid particles in the pulp, but also the state in which the pulp is, and the manner of distributing it.

As regards the quantity of water used per minute, it must obviously not be in excess of a certain amount, for if its depth should exceed proper limits, a sorting action depositing grains of the same absolute weight together would inevitably take place, upsetting and destroying the very purpose of the table; still the opposite extreme of using too little is not less to be avoided, as in that case the current would lack strength, whilst it will be equally apparent that, in order to obtain an even and constant flow, the actual quantity requisite for working a coarse ore must be greater than when dealing with a fine one.

The relative proportions of ore and water in the pulp is subject to quite another consideration—viz. that if "the slimes" are allowed to become too "dark"—i. e. contain too large a quantity of ore grains per cubic foot of water, it would impede and interfere with the free action of the current on each individual grain.

In connection with the condition of the pulp undergoing treatment and its proper distribution, attention must be paid that no straw, shavings, or chips are permitted to get into the ore-box—Germ. Mehlkasten—(D), Fig. 9, as they would

seriously interfere with the smooth settlement of the bed, which should be prevented by stopping them on a grating before they reach the pegging-board (E), Fig. 9. Any large, uneven grains of ore that might form inequalities or furrows on the surface, being caught by a sieve in the box specially provided for the purpose.

As the finer grades of settlings worked on the tables are also more tenacious than the coarser ores, they usually require a teazer or agitator—Germ. Ruhr-gump—to mix them properly with water, an operation that otherwise would be generally performed by merely stirring the pulp in the ore-box with a pole, special care being taken to see that it does not vary in consistency during any one run of ore, whilst the pegging-board must be so adjusted as to distribute the material evenly across its entire breadth, and in such a way that it may fall from not too great a height upon the head of the table, like rain just after a heavy shower running off the eaves of a house.

The influence that the character and quality or timbre of the blow exercises on the work, as it may vary greatly, and is the distinctive feature of the class of tables now specially under consideration, though dealt with last, is by no means the least important of the several points to be kept in view. It is ruled 1st, by the rapidity of succession with which the blows of the tappet-rod (*y*), Fig. 9, succeed each other; 2ndly, by the length of stroke the rod makes; 3rdly, by the initial velocity of the rod's motion from the moment of impact to its termination forward; 4thly, by an instant of rest at the end of the stroke; 5thly, by the force of the sudden blow at the end of the return; and 6thly, by the timbre of the shock itself received on falling against the anvil-block.

Taking them in order, let us see upon what each of these adjustments depend.

First, as regards the rate of revolution of the cam-shaft (which is subject to the power of the motor and its management), since when its speed remained unchanged, the rapidity with which the blows given to the table succeed each other must be in inverse ratio to the length of stroke of the tappet-rod, as will be evident from what follows, it must of necessity be driven faster when dealing with a coarse ore than with a fine ore.

Under the second and third headings we have to consider the amount and the velocity of movement of the tappet-rod, which may be looked upon practically as one, because, as the rate of revolution of the driving-shaft is ordinarily pretty constant, the rapidity of the motion imparted to the rod is generally dependent upon and in direct proportion to the length of its stroke.

In regard to these particulars then, it can be laid down as an axiom, that the finer the grade of ore, the shorter the thrust and less rapid the initial motion of the rod should be, as the swing of the table requires to be adjusted, so as to be neither more nor less than sufficient to shake off the lighter particles of ore, without needlessly disturbing the heavier ones, that are kept in place by their inertia.

The fourth and next condition that influences the result—viz. the period of rest after the stroke, which lasts, perhaps, a second, has the effect of allowing the ore to settle before it is affected by the impulse of the return, and results as a consequence of the shape of the cam, which, even when designed upon the epicycloidal lines familiar in the construction of toothed wheels, is susceptible of this irregularity, owing to the position of the tappet-bar (v), Fig. 9, and its curved extremity.

In the fifth place, there is the strength of the blow, or, in other words, the momentum imparted to the frame in swinging back, that has to be calculated for, which, with a

given length of stroke (the difference in weight of the table under varying loads being disregarded), is regulated by the tension of the chains the frame is hung upon; the action induced having the tendency to drive each separate grain backwards in direct proportion to the Sp. gr. of the minerals composing the ore, and the force of the concussion, when the resistance offered by the water-current, friction, and the inclination of the surface of the bed, is not too great to be overcome; which more or less depends upon the size of the grade of material undergoing treatment, the relative weight of its component minerals, and the degree to which the ore has been already concentrated.

A coarse ore for instance, or one in which there is a marked difference in specific gravity between good and waste, requiring more tension than a fine one, or another in which the different minerals do not readily separate, owing to an equality in their relative weights.

The tension is consequently usually less during the final concentration, than during the preliminary treatment of a raw product.

The chains regulating the tension—Germ. Spannketten—are those the head of the frame is suspended from; and their action will, I think, be clear from the subjoined diagrams, Figs. 44 and 45; for it will be apparent that with a given length of chain, *a b*, whilst the thrust *c d* remains the same in both cases, in describing an arc *b d*, with a tension *b k*, Fig. 44, the table falls through a greater vertical height *h k*, than when with a tension *b e*, in following an arc, *b d*, Fig. 45, it travels through a space equivalent to a drop from *f* to *e*.

The momentum of the blow being relatively more or less (if the tension and thrust are not altered), according as *a b* is short or long, as I have endeavoured to represent, by the extension of a principle illustrated in Gaetzmann's Aufbereitung, by Diagrams 46 and 47, where, though *c d*, *b′ k′*,

and $b'e'$ are similar to the corresponding lengths in Figs. 44 and 45, owing to a' b' being shorter than a, b, h', k', and f', e', are longer, and therefore represent greater *moments* than do h, k, and f, e.

Sixth and lastly, the blow itself may be either of an elastic or inelastic character; the effect of which will be discussed under the next head.

Fig. 44.

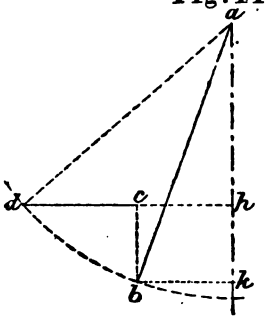


Fig. 45.

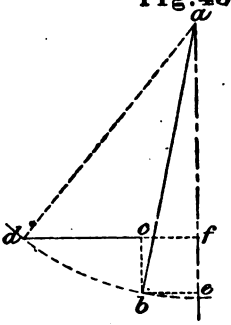


Fig. 46.

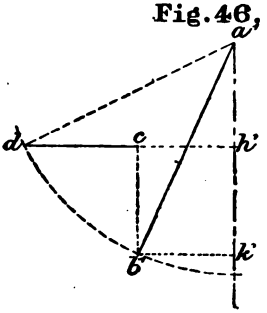
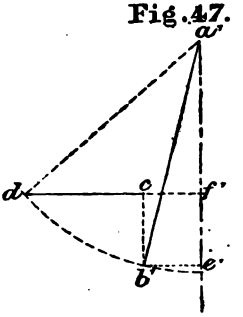


Fig. 47.



Indications upon which the Management of a Table depends.*

A table, working properly, should be covered with a number of transverse waves, their crests being further apart the finer the grade of ore that is undergoing treatment happens to be, and which will be seen following one

* *End*-percussion tables are here alone referred to.

after the other, with more or less rapidity, in regular order, from the head to the foot of the bed, where the tailings are thrown off across the entire width in an even stream. It will be observed, too, that the larger waves near the head of the table appear, so to speak, to catch up and merge into those ahead when about half-way down. Moreover when the water between the waves is free from the dark flocculent turbid appearance, generally seen in front of them (owing to the lighter ore-particles being accumulated and carried all along together), longitudinal ripples may sometimes be noticed on the surface as well.

Should the waves run diagonally, so as to break upon the sides of the frame, the table requires to be levelled transversely (by means of turn-buckles attached to the chains it is hung upon), for it shows that one side is higher than it ought to be. See Fig. 48 (an exaggerated case).

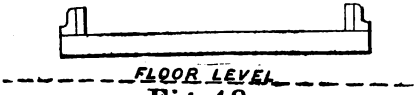


Fig. 48.

The deposit that collects on the table to a thickness of about 8 inches near the head, diminishes gradually in depth towards the foot, and must be more or less solid and compact; it should have a perfectly smooth surface, free from all hummocks, hollows, or furrows, and a cross-section through it should show an even series of horizontal and parallel stratifications, though if exposed longitudinally it would be found to be really wedge-shaped.

When the ore that has accumulated at the top is incompact and only partly clean, it indicates that the tension given the table was too great, whilst its inclination was too little, and that more water, or in greater probability less ore, was needed in the slimes. If, however, it is a case of the whole deposit being too thinly distributed, or of a cross-

furrow having been formed at the upper end of the bed, it proves the inclination of the table to have been too great, or its tension too slight; while the ore was possibly in smaller proportion than it should have been, as compared with the quantity of water used to thin it.

A hummocky top, in which ridges of ore are seen running crossways, denotes a *sudden* alteration having taken place in the normal condition of things, brought about either by suddenly lengthening the stroke, or increasing the number and intensity of the blows the table has been previously receiving, which may induce a movement tending to force an upper layer of settlings back against the headboard (over the heavier ones beneath), resulting of course in a local disruption of the bed, which causes the upper part to buckle; or it may be due to the proportion of ore and water in the feed altering, to a sudden change of inclination, or to excessive smoothness of table surface.

Such inequalities can fortunately be effaced when they first show themselves by a judicious use of the levelling scraper, or "Kiste"; and if the table is afterwards handled properly, they will entirely disappear. But should they be allowed, through inattention, to grow to a large size, there is no alternative left but to break up the bed, and work it over again.

Large longitudinal furrows point to a general incompactness in the deposition of the ore, and may follow from working with too dark a slime, or too slight a tension; but small ones appearing near the foot of the frame—mostly seen when a coarse grade of ore is being operated upon—are generally merely the result of the concussion communicated by a *rigid* cushioning-block—Germ. Prellstock—and far from showing any defective action, are rather to be desired than otherwise, indicating, as they generally do, a loose deposition of the material in the *lower* portion of the

bed, that follows from excessive evenness of size and the absence of fine particles, which, by having settled above, leave interstices that prevent the ore below from binding into a compact mass.

Still, even furrows of the latter kind must be checked in their growth, should they show signs of extending *too* far up towards the head of the table, as can always be done by increasing the tension.

A tendency may also sometimes be observed for the ore to collect in a greater or less degree in the middle than at the sides of the bed, owing to a faulty adjustment of the pegging-board, which must be remedied, by re-setting it, so as to give a more even distribution of the slimes.

Another most faithful index of the condition of things is afforded by a series of thin dark longitudinal lines, the so-called "strings"—Germ. Schnuren—that can often* be noticed, starting into view on the surface of the water just at the instant that the table quivers from the shock it receives; for when everything is working as it ought to do, they should be seen commencing at a little distance from the top of the bed and ending a little way from the end, where they are gradually lost sight of.

If, on the contrary, they commence too high up, something is wrong, and either the gradient of the table, or the delivery of slimes, requires to be increased; whilst if they are too thick and continue too low down, ore is being carried away, which can follow either from excessive inclination or tension, or from the blows the frame receives being too light, at the same time that the ore delivered upon it is insufficiently thinned with water.

When the "Schnurs" are very short and disappear suddenly, reappearing intermittently, the blows are too weak and the angle of fall is too little; whilst should the

* Rarely visible when a *very* coarse or very fine ore is being dressed.

lines appear curved instead of straight, as sometimes happens, the trouble may be traced to an excessive shock, or a side lash, making the table wobble, in consequence of the chains on its opposite sides not being exactly the same length.

It may further be remarked that when the surface of the deposit on the upper third of the table is scraped with "the Kiste," its darker appearance should clearly distinguish it from what collects further down; and on the same principle the tailings escaping from off the end will usually indicate by their colour whether any ore is being carried away or not.

Settlings deposited from a dark-coloured slime—Germ. "Trube"—or on a table which has too small an inclination given it, are generally less compact than those obtained from a similar grade of ore under opposite conditions; for by increasing the strength of the blow, the particles are induced to glide upwards and slip over one another with greater readiness into positions, in more open places.

On a newly planked frame, a bodily movement of the whole deposit not unfrequently takes place, due to insufficient adhesion of the material to the flooring.

Again, should it be found as a general rule that after cleaning a charge, the settlings on the lower half of the bed are so poor as not to be of any value, the table may be unnecessarily long, though in any case the concentrates must not be expected to reach *quite* to the end.

The shock, too, received in falling back, as previously mentioned, may be either of a rigid or elastic character, depending on the construction of the cushioning-block, which is of material importance, as the nature of the one kind of rebound exercises quite a different sort of effect to the other. An inelastic blow, as it packs the settlings less compactly, and therefore allows them to be more easily removed, though it limits the depth deposited to about

4 inches, is best for fine classes of ore; whilst an elastic shock, as it requires less power to drive "the table," and will admit of a thicker deposit and also a heavier blow, is generally thought the most suitable for the coarser grades.

The tailings ought to be frequently tested with "a pan," and in the earlier washings should show but a trace of the heavier minerals in the ore. Mere rule-of-thumb work never pays, and the value of both the concentrates and tailings should be most carefully ascertained, when any doubt exists in dealing with a strange ore, whether certain grades can be profitably re-worked or not. An intelligent comprehension of the capacity and functions of the various machines, as well as careful control being equally indispensable to success in all dressing operations, as there is a certain standard that varies in different cases, beyond which no advantage or profit can be gained, but that if fallen short of, is just as fatal to proper economy and success.

Returning now to the point where I left off the description of the mill at Abertham, one finds that the coarse headings belonging to Class I., as already incidentally mentioned, are worked by themselves on one of the ordinary percussion-tables (P P), Fig. 41, which yields so-called "Ober-schaufel," "Mittel-schaufel," and "Abgang."

The "Ober-schaufel," when there is sufficient collected, is concentrated on side-percussion tables of the Rittinger pattern (M M), Fig. 41 (built with wooden frames, Fig. 49); whilst the "Mittel-schaufel" is re-worked, giving more "Ober-schaufel," that is treated the same way as the first lot.

The Abfluth is worthless (see Dressing-tree).

The middle products, or "Mittlere-graben," from the tanks belonging to Class II., are treated on a separate end-percussion table, and give just the same products as those obtained in the preliminary treatment of Class I.; but the

"Mittel-schaufel" in this case is usually mixed with some fresh ore from the Mittlere Grabens before undergoing a second washing, that gives an "Obere-schaufel," worked like "Ober-schaufel" on a side-percussion table, a middle-stuff, or "Mittlere-schaufel," which is re-washed like "Mittel-schaufel" and waste.

The slimes from the tanks in Class III., after four or five cleanings on the ordinary tables, yield a "Schaufel," which goes to the roasting-furnace, and thence direct to the acid tanks.

The Ober and Obere "Schaufels" accumulated from the different sources mentioned are fed separately by means of revolving feeders—Germ. Drehscheibes—(T), which take the place of agitators, or "Ruhr gumps" to the double-continuous side-percussion tables (M M M M), Fig. 41, which are driven apart from the rest of the machinery by the steam-engine (B), and give an "Ober-erz," "Unter-erz," and Abfluth by the first washing.

Of these products the "Ober-erz" is sent to the roasting-house, whilst the "Unter-erz" is re-worked on an end-percussion table, yielding 1st another "Obere-schaufel" that is returned to one of the continuous tables, and, 2nd, a "Mitlere-schaufel" that goes back to an ordinary table, which finally gives a further quantity of "Obere-shaufel," sent to the Rittinger-table; and some more "Mittlere-schaufel," that is mixed and re-worked with the next lot of ore.

The washing of these last "Obere-schaufels" on the Rittinger yields "Obere-erz," "Mittlere-erz," and "Abfluth," of which the "Obere-erz" goes to the roasting furnace, and from thence to tanks (V), Fig. 41, for treatment with acid; whilst the "Unter-erz" is mixed with the "Mittlere-schaufel" resulting from the last washing on the ordinary table, to which it is likewise returned (see Dressing-tree).

In the Abertham mill the end-percussion tables have

a rounded head like Fig. 11, which is considered in some respects to be preferable to the sloping form, Fig. 10, that is perhaps the most common.

A general idea of the construction of the Rittinger will be gathered from Fig. 49; but as the scope of this pamphlet will not admit of it, I do not here propose treating the subject with any detail, beyond furnishing a few particulars in "the explanation of the plates." It will suffice to say, that experience in this neighbourhood seems to give the preference to a wooden bed, made of 6-inch boards of maple, running crossways, carefully joined and rabbeted, and fastened with wooden pins to a flooring of soft boards underneath, set at right angles to the ones above; from which they are divided by a sheet of well-stretched and tarred sail-cloth.

The working surface, that has an area of 8 feet by 8 feet, forming a double table, has to be carefully planed, and smoothed with pumice after being put together, and is slightly charred with a weak solution of acid, in order as far as possible to prevent the ore-particles from sliding upon it, in opposition to the legitimate forces that should control their motion.

It is worthy of remark, too, that the nature of the blow the side-shaking table receives when it hits the striking-block, is sharp, quick, and decisive; and must be free from all tendency to rebound, rest an instant, or quiver, that are distinguishing features in a table with an end shock.

Further, my own experience leads me to believe, that a particularly essential point in operating the Rittinger and other such concentrators successfully is to ensure as far as possible the most absolute *unvarying regularity* of motion when dealing with any one class of ore, as the effect of sudden changes of speed, such as frequently occur when varying loads are thrown upon the ordinary driving

machinery of a mill, makes itself at once apparent in the work done. Consequently, unless the motor employed is provided with a most sensitive governor or automatic cut-off, tables of this sort have not got a fair chance, a fact that may doubtless account for the apparent prejudice one sometimes finds expressed against them.

To ensure the best work, you should, so far as I have seen, go even a step further, as is done at Abertham, and, if possible, drive them by separate power designed for their use alone, employing either a small well-regulated steam-engine or a water-wheel specially controlled.

The inclination given the double-tables in this mill is from 5 to 6 degrees. They are run at 70 to 80 blows a minute, with a stroke of 1¼ inches to 1¾ inches, and perform a duty of about 10 tons in 24 hours.

The supply of clear water is so proportioned in both divisions as to be greatest furthest away from the point upon which the delivery of slimes take place, i. e. in the corner on the opposite side to the striking-block, otherwise the curved lines of ore would be liable to get confused and mixed with the waste.

The roasted "Ober-erz"—Germ. Guter-erz—obtained as before explained, in the different stages of dressing, is put in tubs (V V V), Fig. 41, 2 feet high, and 3 ft. 7 in. in diameter, that are filled to within 8 or 9 inches of the top with the ore, upon which crude hydrochloric acid is poured till the space is nearly full. After standing in that condition for several days, during the course of which the contents of the tubs are occasionally agitated with a stick, the liquor, that now looks almost black (from the iron and other impurities it has taken up), is drawn off; whilst the leach, that by this time has assumed a light yellowish colour, after being cleansed with clean water and washed once on a side-shaking table, is sent to the smelter.

The "Schaufel" obtained from the end-percussion frames working the slimes belonging to Class III. is treated exactly the same as above, only that instead of fresh acid being used, it is leached with what has been already once used upon "Ober-erz."

The last washing on the Rittinger, after treatment with acid, gives headings of tolerably pure and concentrated ore, sent to the smelting-works, and waste, consisting of the lighter impurities, &c., that is thrown away.

CHAPTER XV.

SMELTING.

THE metallurgical treatment of the ore presents no special features of difference, except in the refining, from the course followed at Altenberg, and may therefore be described in a few words.

The smelter (L), Fig. 41, is next the stamp-house, and contains a dry-stamp battery, an ordinary reverberatory roasting-oven, a liquating-furnace, and one shaft furnace. This last is 7 feet high, and measures 12 inches in breadth at the back, 18 inches in breadth in front, and 16 inches in depth from breast to back at the level of the hearth, which has a fall of about 3 inches forward.

The blast is supplied by a 2 ft. 6 in. rotatory fan blower through a single 2-inch twyer, inclined downwards, that enters at the rear about 3½ inches above the back of the hearth.

The tap-hole is 2 inches square, and discharges into a square stone sump, 27 inches long, 16 inches broad, and 4 to 5 inches deep, that corresponds with the "Vortiegel" (mentioned elsewhere), and is connected by a channel with an iron bowl (answering to the "Stechherd"), 16 inches in diameter, which is set in the floor of the building, and out of which the metal is ladled into moulds.

The furnace-slags are stamped dry in a special battery provided with a wooden bed, and are afterwards cleaned on

an end-percussion table to recover the globules of tin they contain.

The bars obtained when the metal is cast, are not refined the same way as at Altenberg, being liquated in the furnace, Fig. 50, instead of on an iron plate.

The arrangement for doing this is most simple, consisting of a stone shaft (A) 2 ft. 2 in. square inside, with a sloping iron hearth (B) that has an opening (C) in front 20 inches long, and 2½ inches high; whilst above it, at the height of about 1 foot, there are a series of grate bars (D) arranged side by side.

The operation is conducted by piling eight or nine blocks of tin (each measuring, say, 14½ inches by 5 inches by 4½ inches) at a time upon the grate (D), and keeping up a fire underneath until the metal above has all melted and run down through the glowing charcoal on the hearth, and thence into the iron pan (P), which is in front, and is nearly 2 feet deep and of about the same diameter.

The dross is left behind in the charcoal, and is returned to the shaft furnace on the next occasion it is in blast; whilst the tin is ladled out of the pan (P), and cast into bars, ready for shipment and sale.

EXPLANATION OF THE PLATES.

Fig. 1 represents a level driven from firm ground (A) through the "Stehenden Bruch" (B), into the "Lebendigen Bruch" (E) with a "Flugel-ort" (C), a "Schub-ort (D) and an open space (H) above the timber, which for the sake of clearness is shown only partly packed with attle (*c*).

Fig. 2 is a cross-section on the line *a—b*, taken through the main gallery.

Fig. 3 shows the timbering inside one of the main galleries at the commencement of a Flugel-ort (C) isometrically, as a drawing in perspective would not have answered the purpose so well; but it must not be supposed that a shaft or winze (the only position from which such a view could be really obtained) is ever sunk through the "Bruch." Were it so, in this instance, the two opposite adjacent sides would be shown.

In the cross-drift (C) there is a dividing-piece (*f*) between the posts, set half-way above the floor, in addition to the usual one at top (*h*), Fig. 1.

Fig. 4, plan of Mill No. 1, used to concentrate tin ore at Altenberg, Saxony, contains a plant that includes:—

8 Batteries of Stamps (E)	4 Settling-boxes (G)
8 Settling-tanks (H)	4 End-percussion tables (A)
1 Tye (*d*)	3 Inclined-tables (K)

The necessity in designing a mill of allowing sufficient room for the proper manipulation of the machinery it is to contain, which is too often sacrificed to a false idea of economy, might here seem to have been carried to quite an opposite and unreasonable extreme. But it should be explained that the vacant space behind the tables was formerly occupied by other plant, since removed.

Figs. 5 and 6 represent one of the stamp-batteries in side elevation, partly in front elevation, as well as vertical side-section, and show the battery posts (*a a*) that are mortised to a firm foundation-block (*b*); above which, at a height of about 7 inches, sills (*c c*) are let into the

posts to give greater solidity to the bottom of "the coffer" (*d*) that rests upon them.

The sides of the coffer are nailed and rabbeted together, and spiked to the end-posts; whilst to give greater strength, as a number of batteries are parallel to one another, horizontal struts (*k*) are put between them.

Fig. 7 gives a plan and detailed longitudinal section of the settling-boxes against the wall (W), showing the gutter (F) with the channel ways (*a a*), one shut, the other open; the overflow slit (*h*); the holes stopped with plugs (*c c*); the iron shoot (*l*); the distributing-block (*d*); and the cross-sills (*s s s s*), placed underneath, to keep the boxes off the ground.

Fig. 8 represents a plan of the slime-pits, and explains itself; (*a a a*) are the passage-ways by which the slimes pass from one compartment to another, after having found entrance to the launder (*b*) through the movable door (*c*). The tailings-sluice (*h*) is kept open or closed by a sliding-gate (*g*).

Fig. 9 is a drawing of an end-percussion frame, that has been specially prepared for this pamphlet by the author, after a careful consideration of the details and measurements of a large number of examples known to him in all parts of Saxony, so as to represent as nearly as possible one of the best and most serviceable forms of wooden table commonly met with, and is meant rather as a typical example than to illustrate any particular case.

Three views are given, viz. plan, side-elevation, and end-elevation of framing, the lettering in each corresponding with the others.

A is the "Unterfass," B the bed of the table itself, C the platform from which the work is more or less controlled, D the mixing-box or mehl kasten, E the distributing or pegging-board—Germ. Happenbret—T the posts, and F the clear-water launder.

The framing of a double table consists of nine posts (T T T) mortised and pinned to three separate mud-sills (*q q q*), that rest upon four transverse ties (*k k k*).

The posts are supported by the struts (*m*, *n*, and *n'*) that are let into them, as well as into the mud-sills, and are fastened securely at both ends with iron straps.

The three posts at the lower end are united at the top by a cap-piece (*r*), underneath which there is a roller (*d*) fitted with a pawl and ratchet-wheel arrangement (*g f b*), and two iron bands (*e e*) pierced with holes for the introduction of levers, so as when necessary to raise the foot of the table, that is suspended from hooks (*h h*) by the chains (*c*), fitted with turn-buckles (*c'*) for closer adjustment.

The six posts at the upper end are also strengthened by distance-pieces (P P P) set between each pair, that serve as joists for supporting the floor (C). The top of the three rearmost ones carry the bearings of the roller the tappet connecting-bar (V) swings upon.

The arrangement for receiving the rearward thrust of the table in falling, consists of a cushioning-block (*s*), separated from a backing-baulk of timber (*s'*) by bolster-pieces (X X).

Piers and buttresses of masonry give rigidity, and prevent any bodily movement of the framing taking place backwards, supporting as well the wooden pillows (*t'*), to which the plummer-blocks that hold the bearings of the cam-shaft (*t*) are bolted.

Other accessories of the table are the tappet-rod (*y*) and the pins (*l*), to which the chains are fastened; whilst there is a gutter (*a*) at its foot to receive the tailings running off the splash-board (*a'*), when the bridge (*a''*) is not used to carry them over the gutter, into the "Unterfass" (A).

Where the drawing has been broken, all the necessary dimensions are given upon it.

The figures that follow, up to Fig. 18, show the separate parts of the table, Fig. 9, in detail.

Fig. 10 shows the table proper, in longitudinal section and side elevation, illustrating how it is actually built.

Fig. 11 is similar to the last figure, only on a larger scale, and with the difference that the bed here has a rounded instead of a step-form of head. The iron racks (*a*) serve to regulate the tension by moving the end rings of the upper chains along them.

Fig. 12 gives back and end views of Fig. 10.

Fig. 13 is a plan of the under side of the same table.

Fig. 14 shows a front elevation and vertical section (taken along *a—b*), as well as plans both of the upper and under side of the cast-iron target-plate, that is fitted and bolted to the front of the cushioning-block (*s*), Fig. 9. This casting has a square hole (*c*) running through the centre of the projecting target, into which a buffer, Fig. 16, fits tightly; whilst on each side there is a hole with a square counter-sunk recess on the outside, for the reception of the $1\frac{1}{4}$-inch lag-screws, or screw-bolts, that hold it in place.

The channel-way (*d*) on top is provided with four lugs (*ff*), the purpose of which will be explained in what follows.

Fig. 15 gives a plan, besides side and end elevations, of an iron shoe that has two wings (*f' f'*) so arranged as to fit into the space between the lugs (*ff*) on top of the target-plate, in order to form a guide for the tappet-rod (*y*), Figs. 9 and 13.

Fig. 16 represents the buffer before alluded to, which is strengthened by an iron band shrunk on to its end.

Fig. 17 shows the shape of the cast-iron face-plate (*h*), Fig. 13, that is bolted to that part of the back of the table which should come in contact with the anvil-block or buffer.

Fig. 18 furnishes a side and front elevation of the tappet connecting-bar (V), Fig. 9, showing the roller (A) with bearings, and the tappet-bar (V) with its connecting arm (*k*), joined by a tie-rod and

cross-bar (*c*), as also the tappet-rod (*y*). The tappet arm, it will be noticed, consists of two parts, viz. the sliding tappet-bar itself (V) (sheathed at the end with an iron armature that acts as a tappet, and can be moved up or down by the winch-handle (*h*) that works a square-threaded screw), and an outer casing (*b b b*) serving as a guide, that is firmly bound and clamped together with iron girdles, plates, and bolts.

Fig. 19 gives plan and elevation of a "tye"—Germ. Schlämmegraben—provided with a wooden pipe (*a*, shown half in section), for clear water, which can be cut off or let on as required by means of a cock above; a scaffold or head-box (*b*) with a lath (*f*) nailed along the front of it; a head-board (*h*) with a splash-plank (*g*)—Germ. Tropf-leiste—before it, to direct the discharge from the head-box properly downwards; and a foot-board (*s*) with plug-holes for the escape of tailings, that are led into the gutter (*t*) by the housing (*r*) round the holes.

Fig. 20 represents a plan as well as longitudinal and cross-sections of an inclined-table, or nicking-buddle—Germ. Glauchherd—set up against the side of a wall, to which the clear-water-pipe (*a*) is permanently fixed with staples; whilst in the same way the "Stein-trogs," which will be again referred to, are supported on wall-brackets. It may also be noticed that the inclination of the bed can be varied by inserting wedges (at *d*) underneath; and that the corners where the sides and flooring join ought to be rounded off, as shown in the enlarged cross-section, by letting in moulded slats specially shaped with that idea.

Fig. 21 shows the roasting furnace used at Altenberg in vertical and horizontal sections, full details of which will be found in the text.

Fig. 22 is merely a general view of the same furnace represented in Fig. 21, to give a fuller idea of its details and connection with the old form of condensing chambers (*k*), that used to be constructed of wood (supported as is seen, on wooden trestles), but they are now universally built of stone in all modern works.

Fig. 23 furnishes a horizontal section of the chambers on an enlarged scale, with chimney (*a*).

Fig. 24 illustrates an improvement upon the foregoing arrangement, though the dimensions of the chambers, which have been kept the same for the sake of comparison the better to convey the idea intended, would naturally be considerably modified in practice, to suit the advance that has been made of late years in determining the size of passage-way that is most conducive to a settlement of "the fume."

Fig. 25 gives a plan and vertical section of an arsenic-kettle, already fully described. It is only necessary to add, that it is on the inside of a building, of which H is the outer wall; and that the ash-pit (P) is provided with a regulator door (*y*).

Fig. 26 shows a side and front elevation of the scraper or "Kiste" that

is used to distribute and spread the ore upon the nicking-buddle, the difference between it and the one used to smooth the ore on the end-percussion table being that whilst the handle of the former is only about 14 inches in length, that of the latter is several feet long, and its blade is rather narrower.

Fig. 27 gives side and front views of a brush made of pine boughs used in connection with the "inclined-table."

Fig. 28 represents plan and side elevation of the "Stein," or "Sichertrog" (A) before spoken of, resting on a bracket (B), which is also shown apart in end elevation.

Fig. 29 furnishes a front and side view of the wooden knife used to collect the concentrates brushed out of the ore.

Fig. 30 gives a side elevation of a knocking tub (K), like K, Fig. 40; and of the leaching tub (A) used in the extraction of bismuth.

Fig. 31 shows the general arrangement of the distributing and precipitating troughs employed in the bismuth process, which for convenience sake are mounted on trestles.

Fig. 32 is a representation of a bismuth melting furnace, in front elevation as well as vertical side-section. Its chief peculiarity lies in the sheet-iron cylindrical mantle (A) and hood (B) above the crucible (*c*), as the former can, when desired, be moved to examine the state of the melt by means of the handle (*a*), without disturbing the upper part, which is kept in place hanging from hooks (*b b*) riveted to its sides upon iron chains.

The cover of the fire-place consists of two fire-brick slabs (*c c*), with a semicircle cut out of the long side of each, so as to form a round opening in the middle.

Fig. 33 shows the dipping-ladle used with the furnace, Fig. 32.

Fig. 34 shows the shape of the ingot-mould in which bismuth is generally cast.

Fig. 35 shows the ore-scoop employed to charge the crucible (*c*), Fig. 32.

Fig. 36 presents a vertical side-section and plan of the large or ore-smelting shaft-blast-furnace of the type known as a "Spur" or "Gutter Ofen," used for smelting tin at Altenberg, a full lettered description of which will be found in the text.

Fig. 37 is a vertical section through the middle of the small shaft furnace, "Schlacken-treib Ofen," employed in connection with the larger one (Fig. 36) for the so-called "refining of the slags."

Fig. 38 represents an ideal section through the axis of the granitic cupola that contains the tin deposits at Zinnwald, exhibiting the beds or Flötze (*a a a*), intersected by a vein or gang (*c c*), supposed to enrich the rock on either side of it.

Fig. 39 is an actual section sketched in the workings.

Fig. 40 gives a plan and section (along the lines A B C D) of the wolfram dressing-floors at Zinnwald, containing a plant of :—

1 eight-stamp battery, with ore-bins	S
2 water wheels	F F′
2 percussion tables	G G
12 settling-tanks	H
1 tye (schlämme graben)	P

and shows also the position of a partly dismantled stamp-battery (S′). The leet (T) for distributing the water to the wheels, as well as the gutter (*a*) that carries the battery-slimes to the settling-tanks, from whence they pass through the tailings-launder (*a*′), to the slime-pits outside.

Fig. 41 is a plan of the stamp-house and dressing-floors at Abertham, Bohemia; containing :—

Steam-engine	B	Side-percussion tables	M M
Stamps	C C	End-percussion tables	P P
Pointed-boxes	F F	Boiler	S
Settling-tanks	G G	Leaching-tubs	V V

The principal details of the side percussion tables are also shown, viz. :—

The hopper	*q*	The revolving screen (for removing chips)	*l*
The fly-wheel	*m*	The gutter (for conveying the pulp)	*t*
The pulley	*n*	The pegging-board	*w*
The cam	*o*	The clear-water tank	*p*
The tappet-beam	*r*	The spring	*s*
The revolving feeder or "drehscheibe"	T		

Fig. 42 presents a front view of a Cornish stamp-battery, details of which will be found in the text.

Fig. 43 is a longitudinal section through the Gefälle (*a*) and Grabens (*g*) that form the settling-tanks, G G, Fig. 41, fed by the gutters *a*′, *β*′.

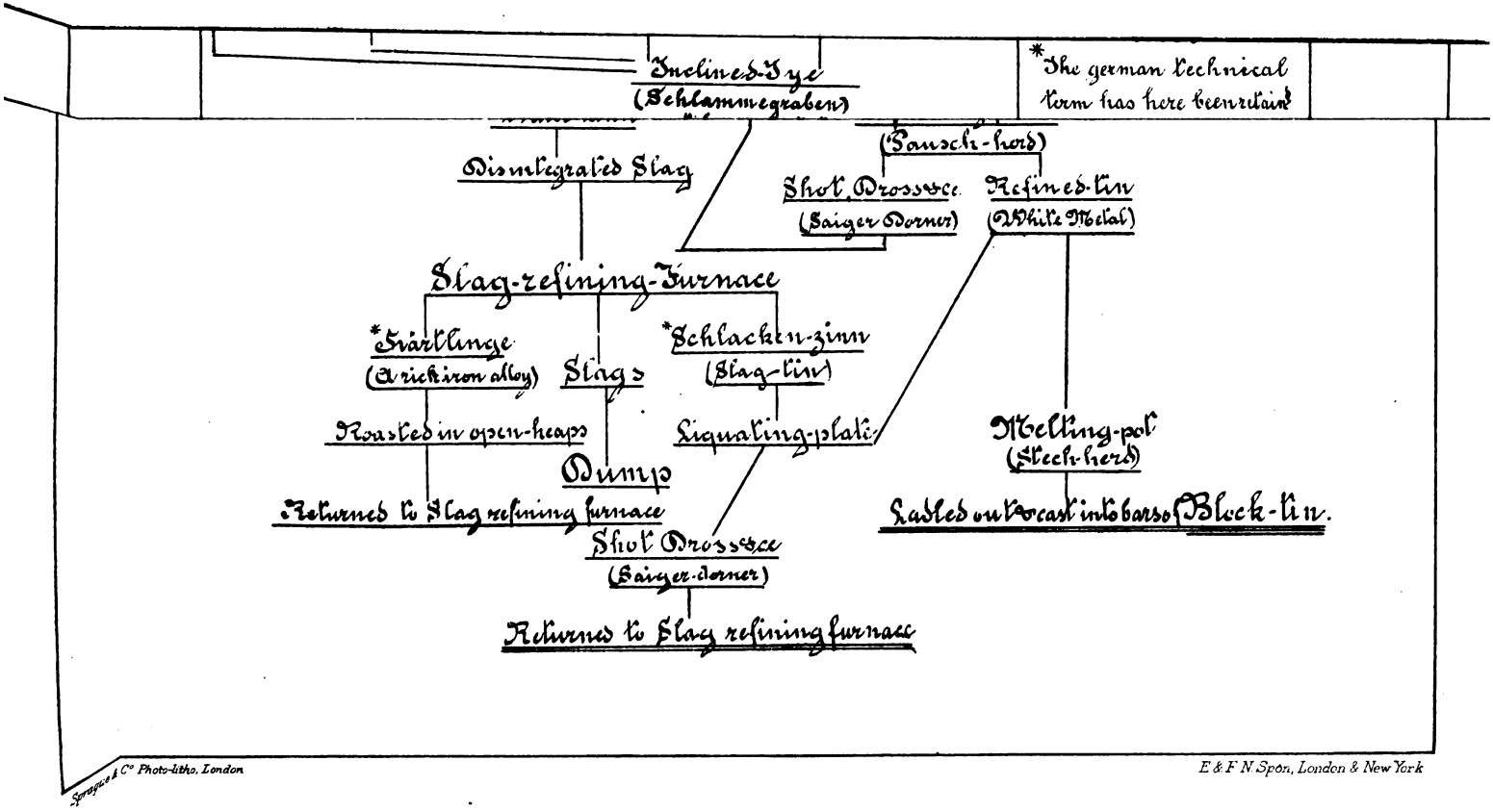
Figs. 44, 45, 46, and 47, see page 66.

Fig. 48, see page 67.

Fig. 49 gives side and front elevations of the framing of a side-percussion table, showing the spring (*s*), water tank (*p*), and the iron-rods (*h h*), provided with turn-buckles, on which the table is hung.

Fig. 50 represents the liquation furnace, in vertical section, that is used at Abertham.

LONDON:
PRINTED BY WILLIAM CLOWES AND SONS, LIMITED,
STAMFORD STREET AND CHARING CROSS.



Sprague & Co Photo-litho, London

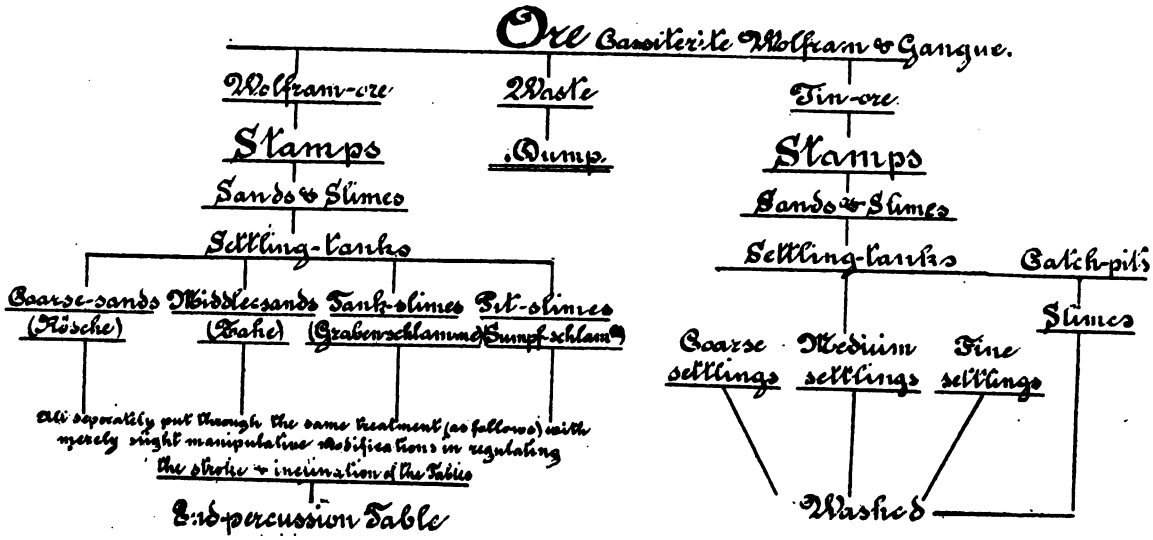
E & F N Spon, London & New York

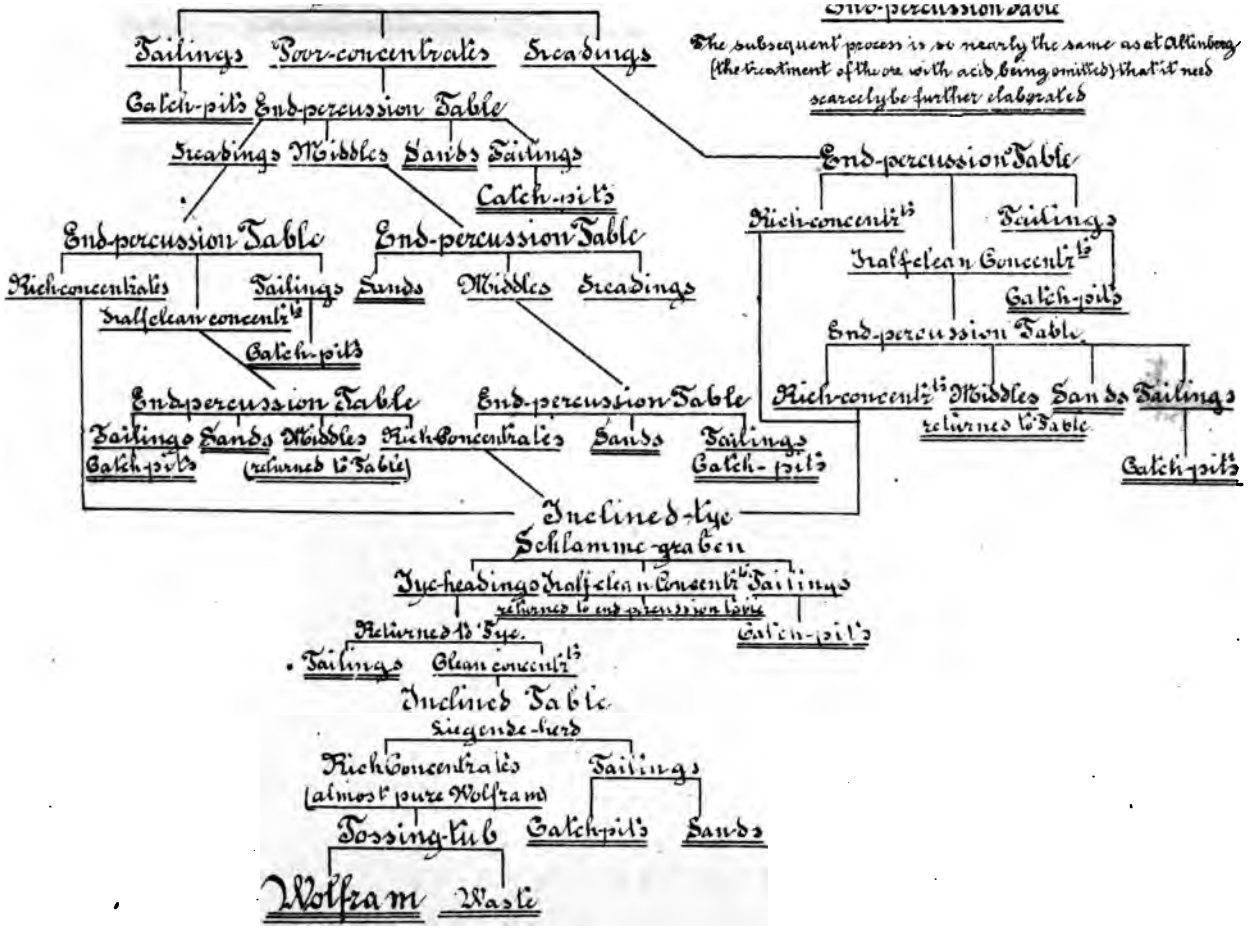
Dressing-Tree

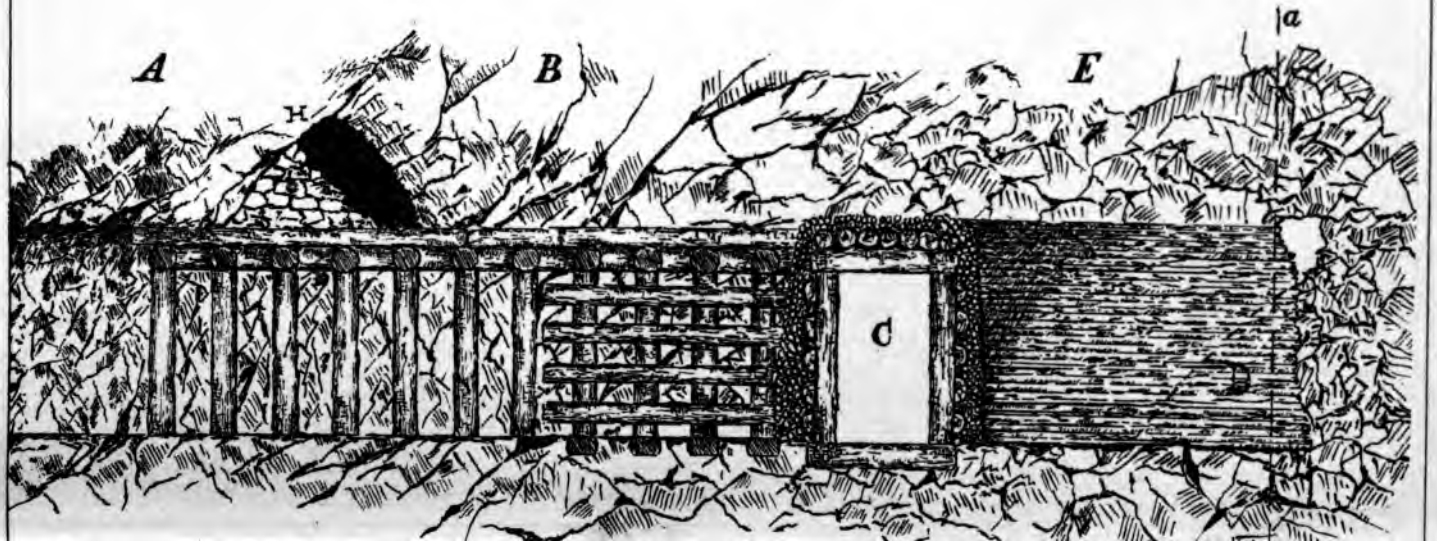
Showing the method of treating the ore at

Zinwald

After reaching the Sorting-ground




Tailings
Poor-concentrates
Treadings
Catch-pits
End-percussion Table
Treadings
Middles
Sands
Tailings
Catch-pits
End-percussion Table
Rich-concentrates
Tailings
Half-clean concentr.
Catch-pits
End-percussion Table
Sands
Middles
Treadings
End-percussion Table
Tailings
Sands
Middles
(returned to Table)
Catch-pits
End-percussion Table
Rich Concentrates
Sands
Tailings
Catch-pits
Inclined-tye
Schlamme-graben
Tye-headings
Half-clean Concentr.
Tailings
returned to end-percussion table
Catch-pits
Returned to Tye.
Tailings
Clean concentr.
Inclined Table
Siegende-herd
Rich Concentrates
(almost pure Wolfram)
Tailings
Tossing-tub
Catch-pits
Sands
Wolfram
Waste
Ore-percussion table
The subsequent process is so nearly the same as at Altenberg (the treatment of the ore with acid being omitted) that it need scarcely be further elaborated
End-percussion Table
Rich-concentr.
Tailings
Half-clean Concentr.
Catch-pits
End-percussion Table
Rich-concentr.
Middles
Sands
Tailings
returned to Table
Catch-pits


A
B
E
a
H
C

Scale 1/8" - 1 ft

Fig-2-

C

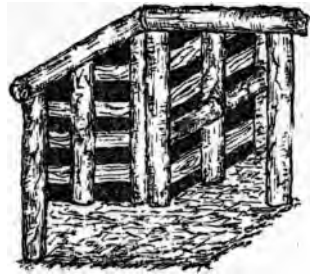


Fig-3-

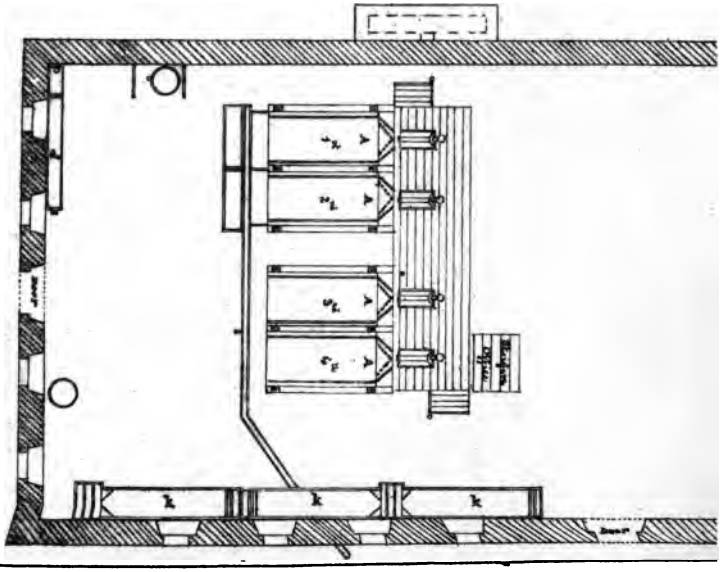
Photo-litho. London.

E & F N Spon London & New York

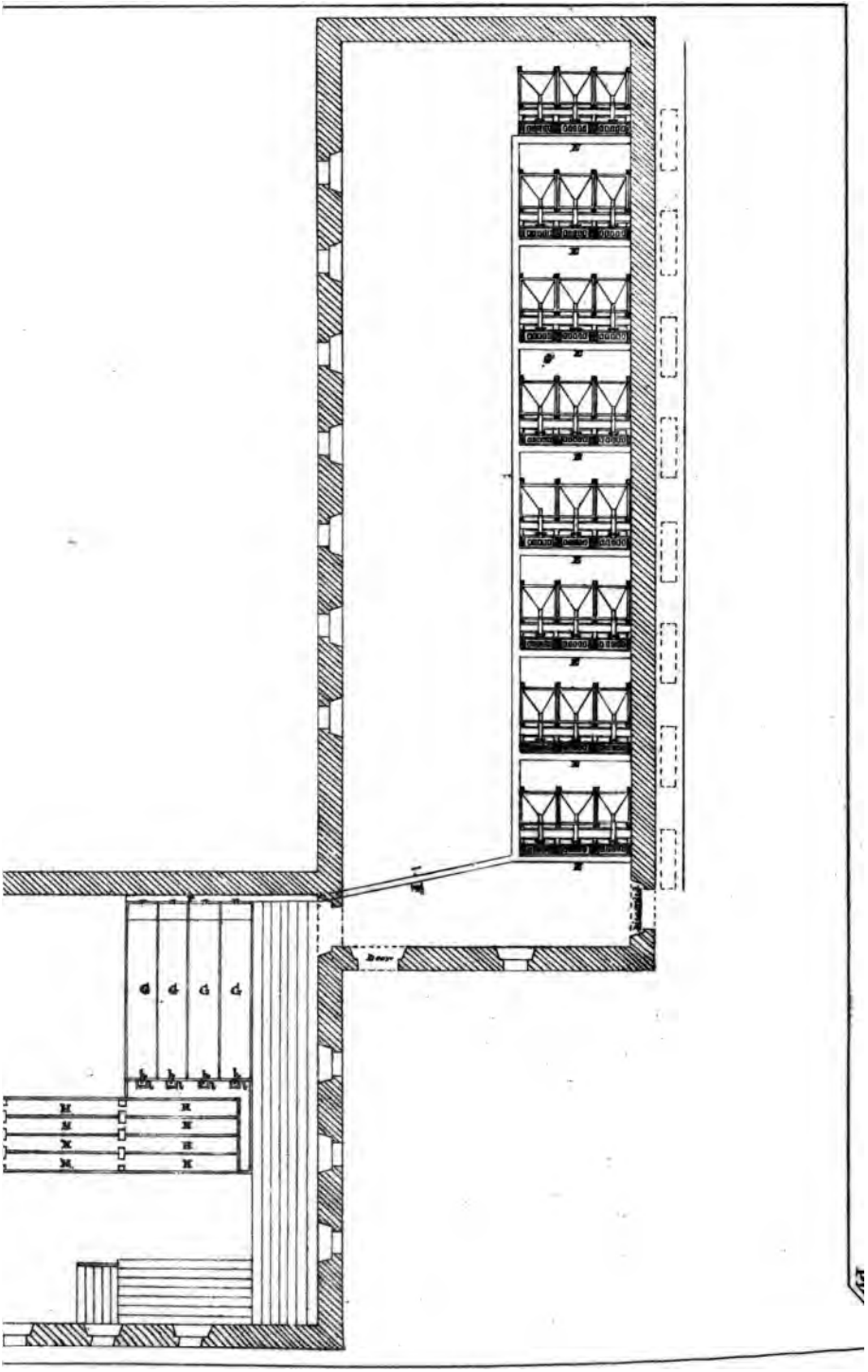
Sprague & Co. Photo-lith. London

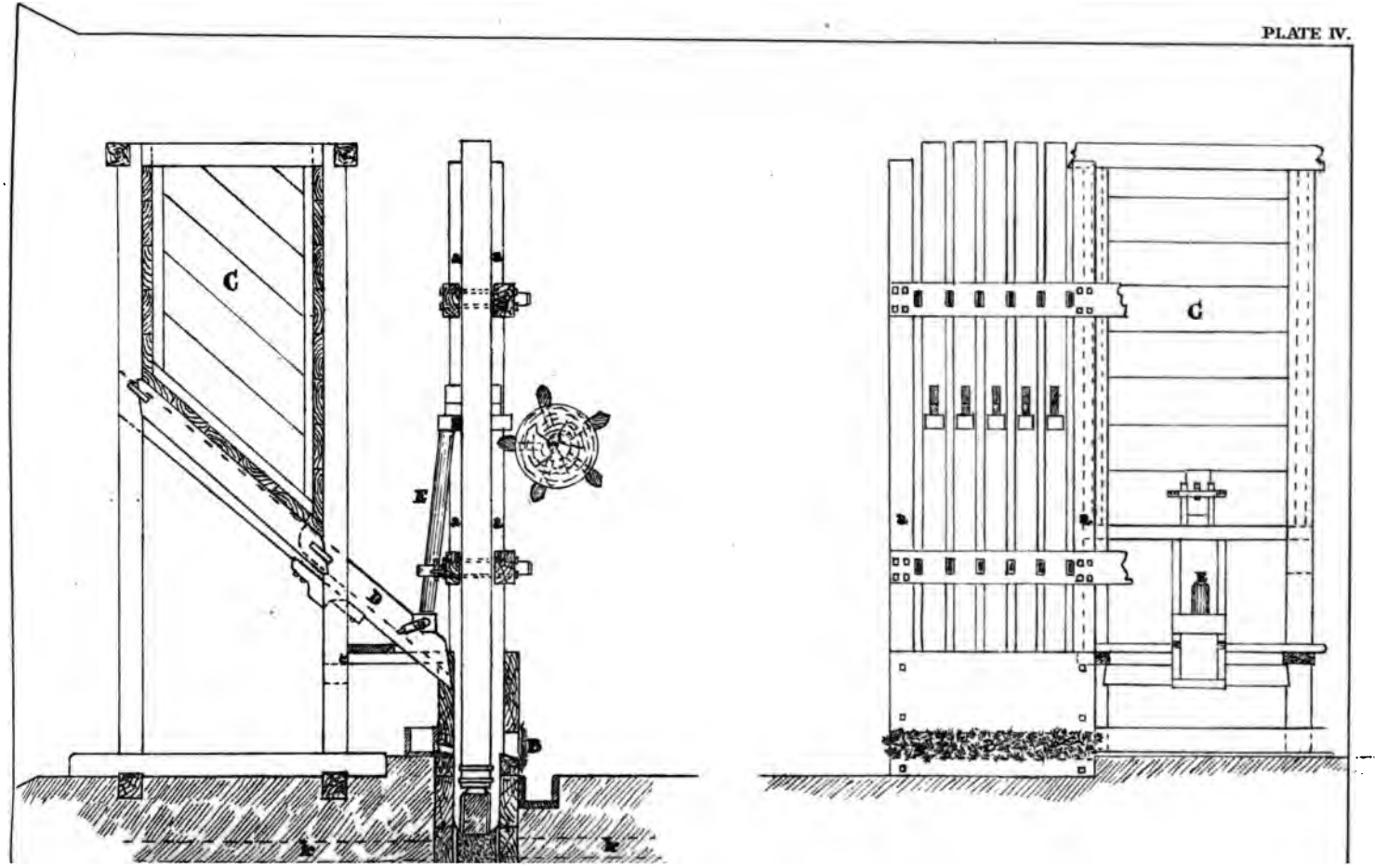
PLAN of MILL NO. 1. ALTENBERG

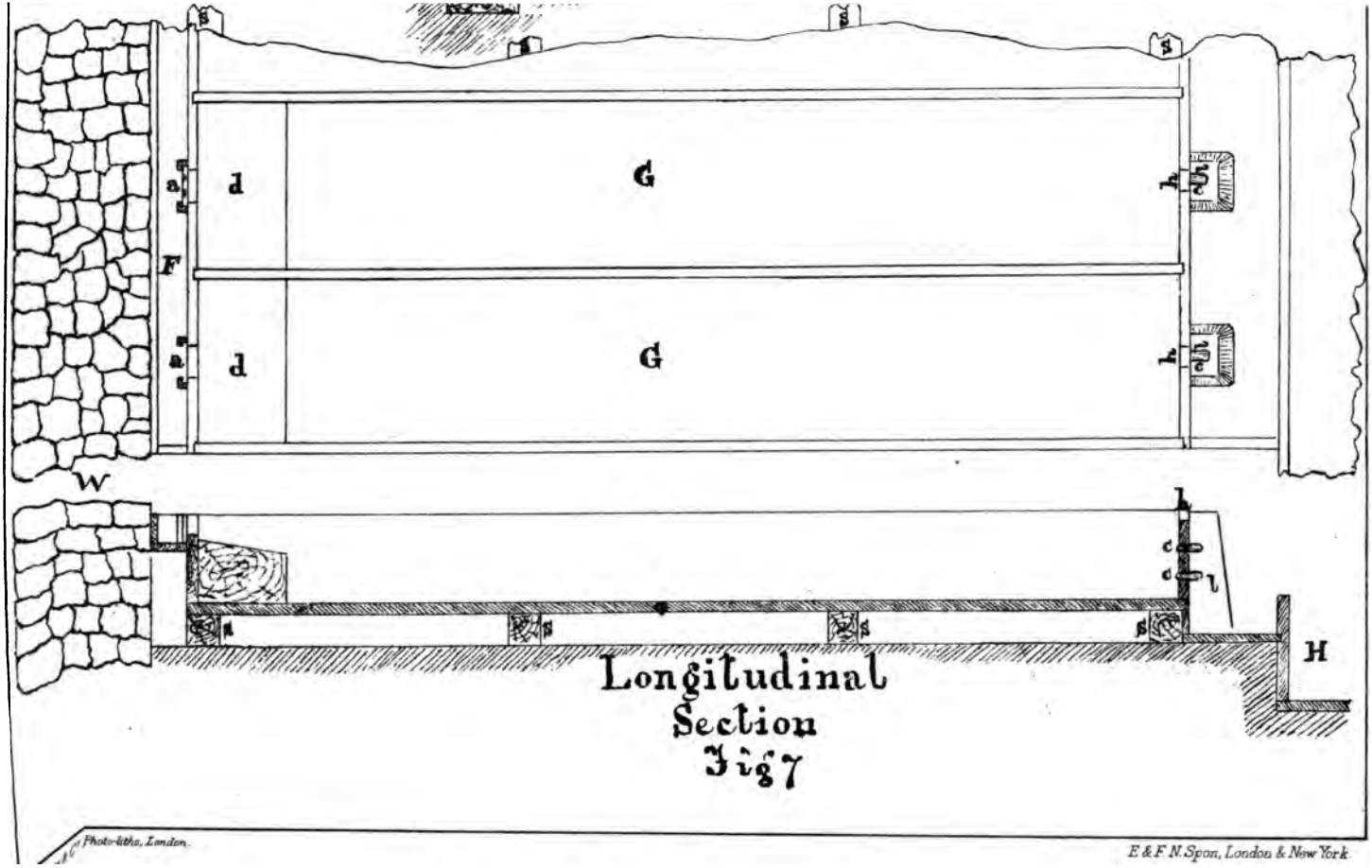
Fig 4.



F. & F. N. Spon, London & New York


Door
G
G
G
G


C
E
C



Longitudinal Section
Fig 7

Photo-litho, London.
E & F. N. Spon, London & New York.

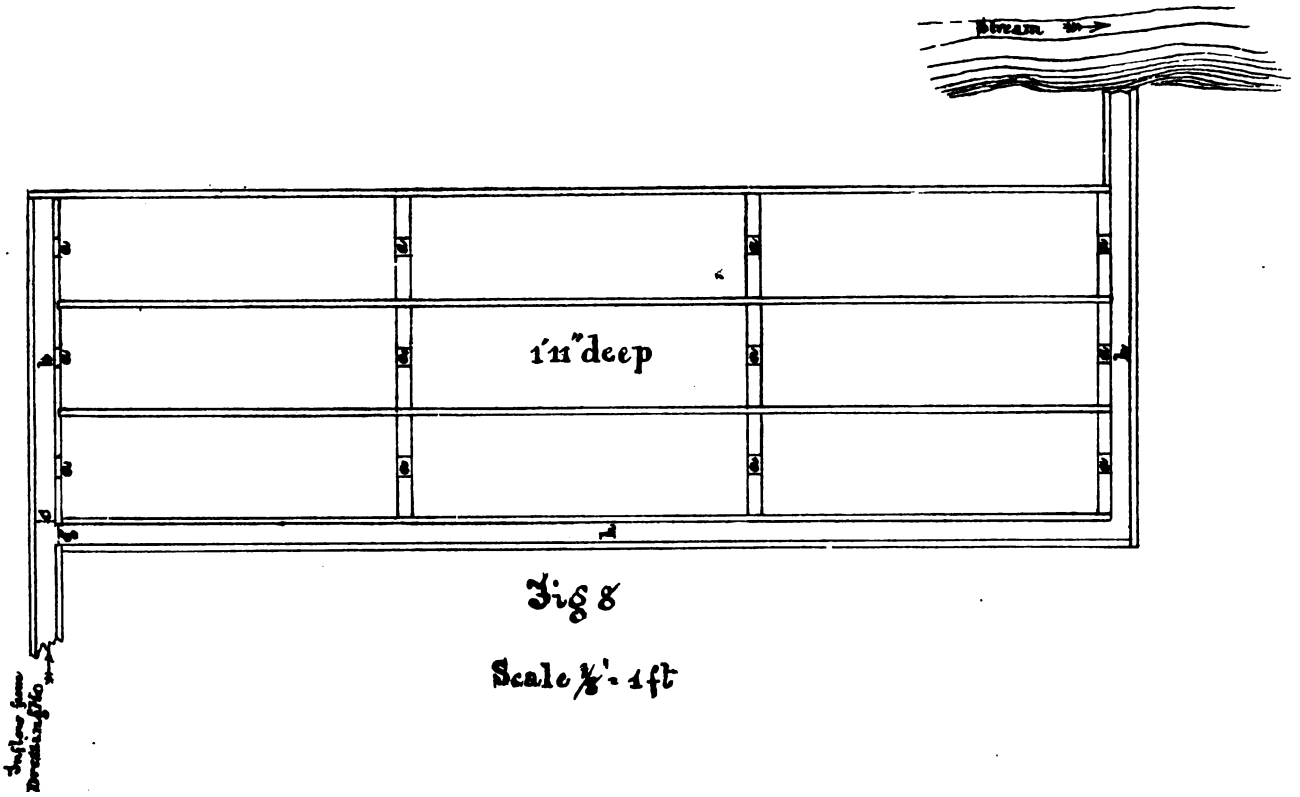


Fig 8

Scale ½" = 1 ft

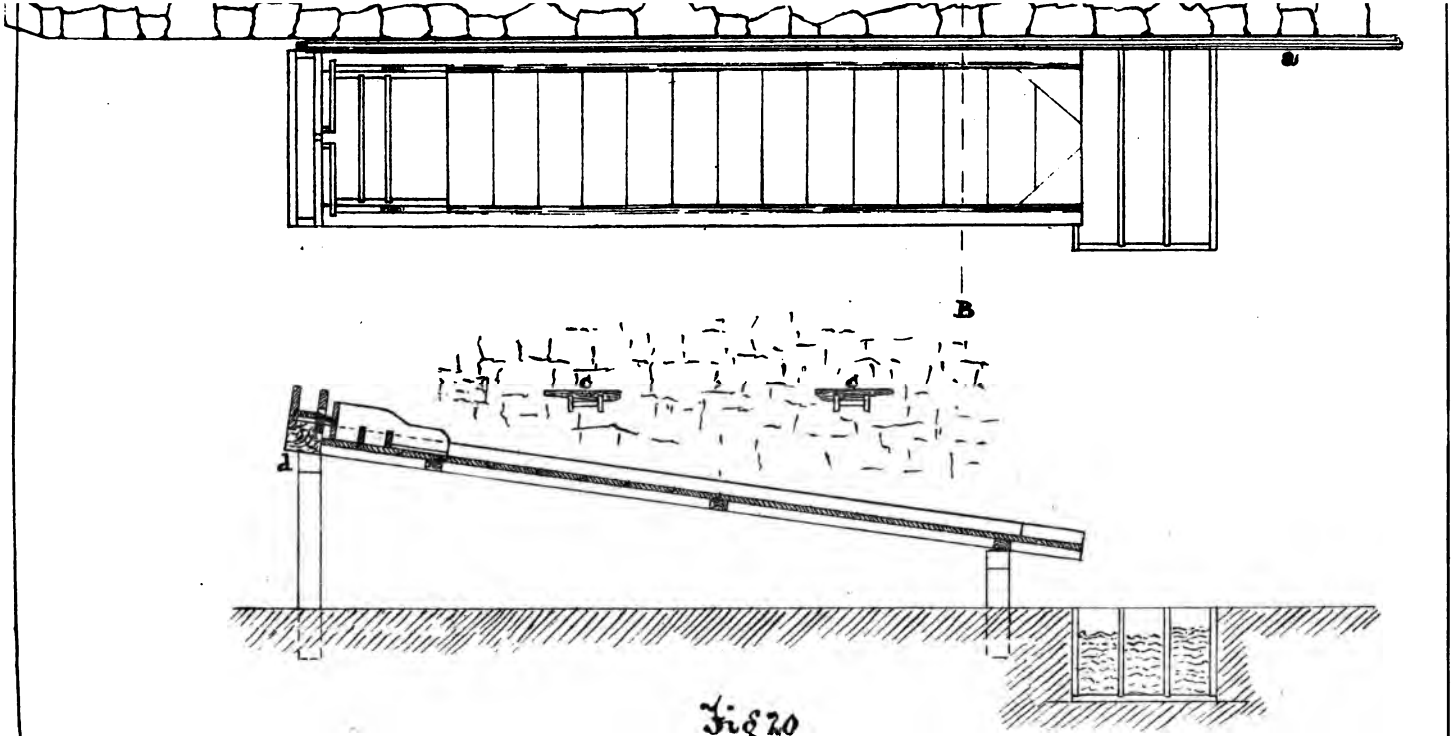
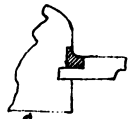
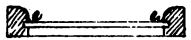


Fig 20
Scale ¼ = 1 ft

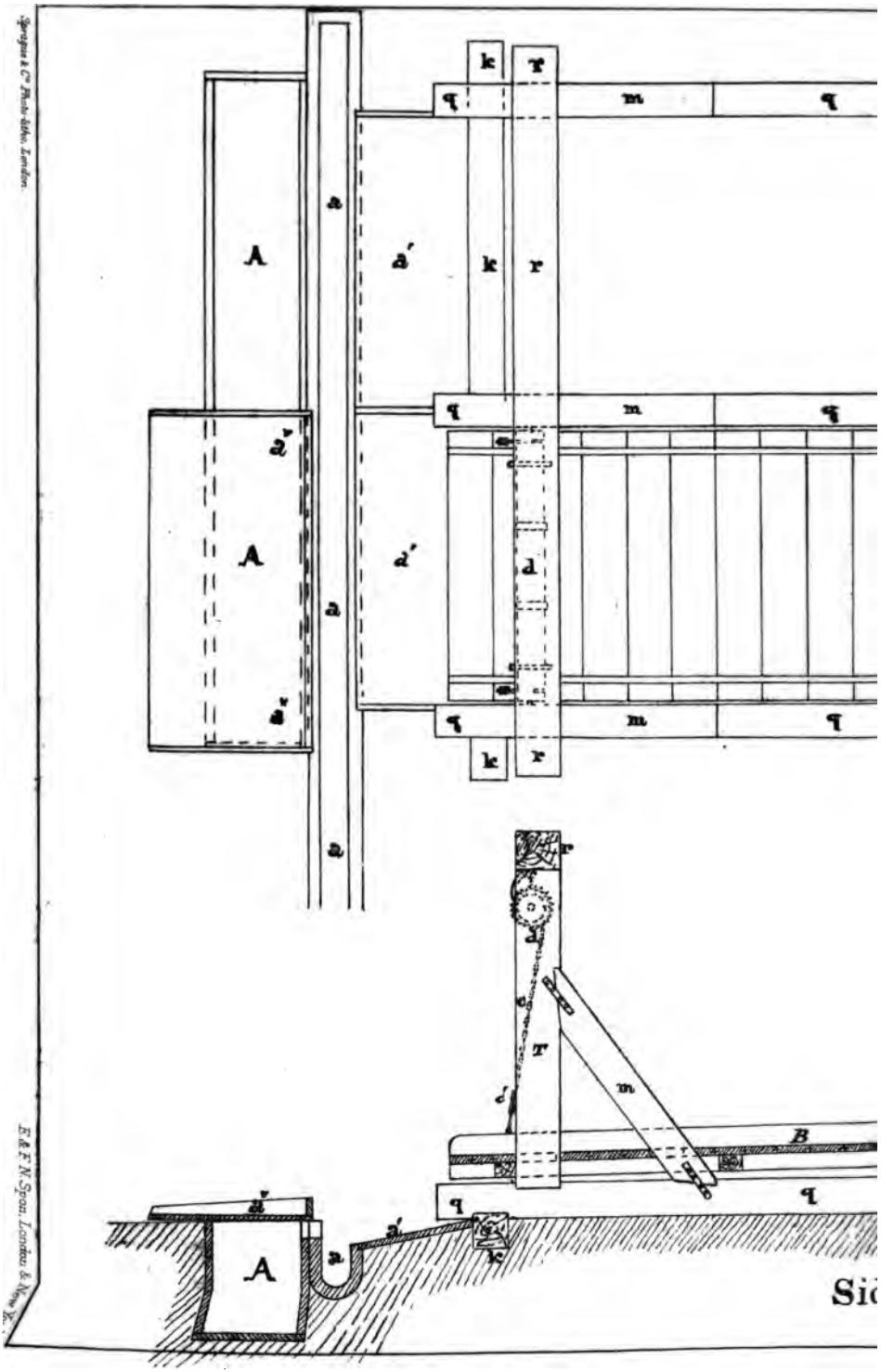


Sec enlarged



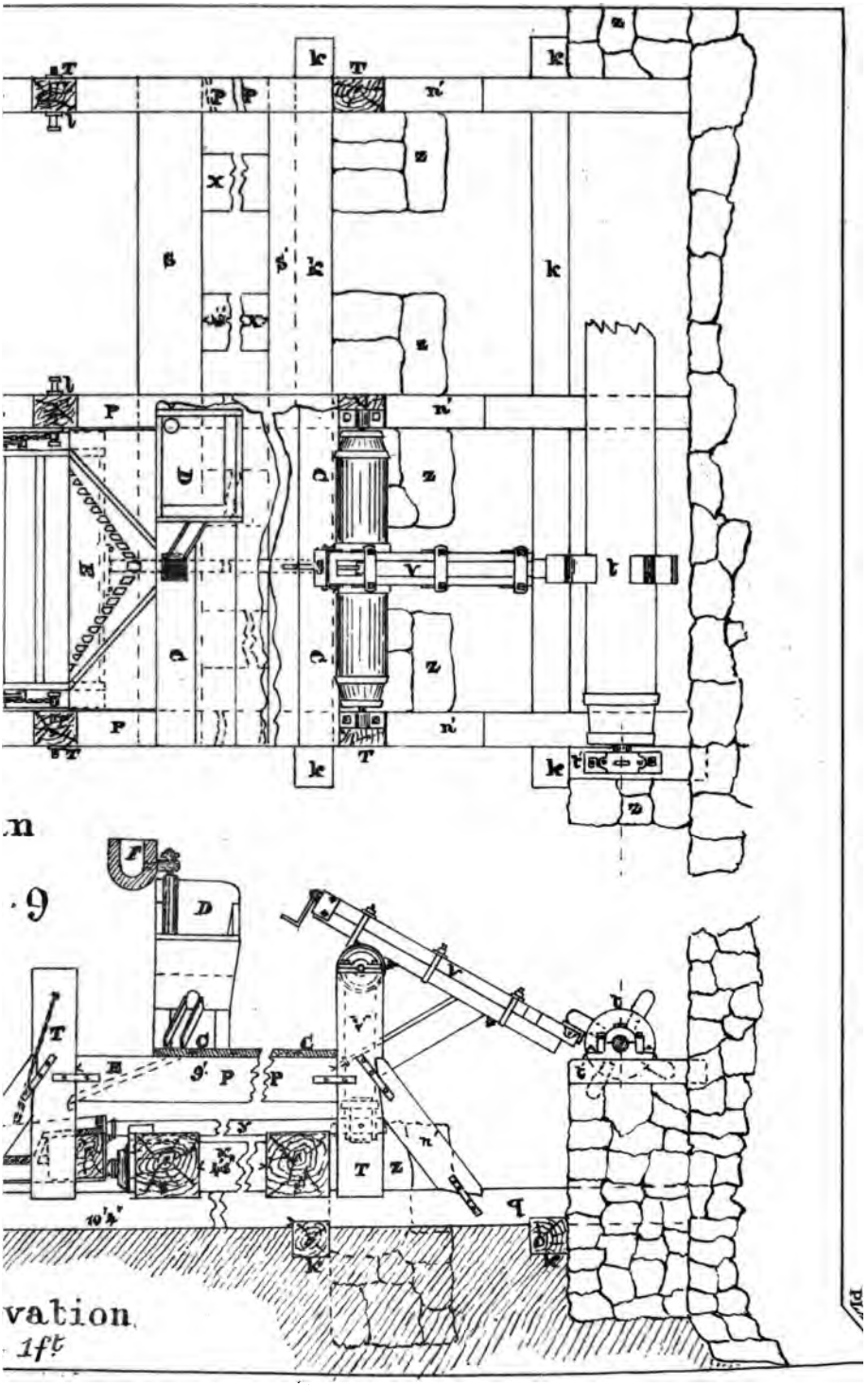
Section (through AB)

F & F N Spon London & New York



Sprague & Co. Photo-litho. London.

E. & F. N. Spon, London & New York.


n
9
vation
1ft

Scale 1/12 Nat. Size

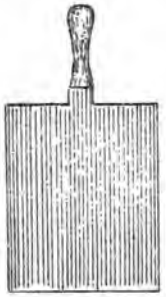


Fig 29

Fig 27

Fig 26

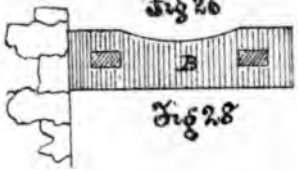


Fig 28

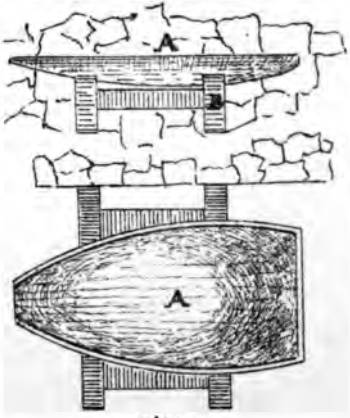
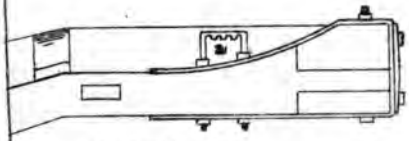


Fig 28



Scale 3/8" = 1 ft

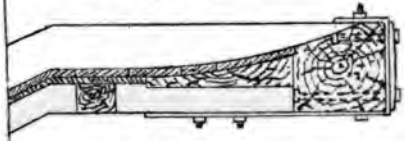
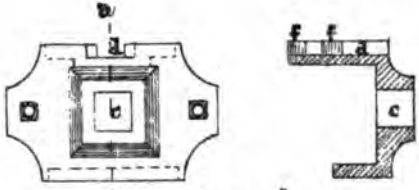


Fig 11



Scale 1/2" = 1 ft

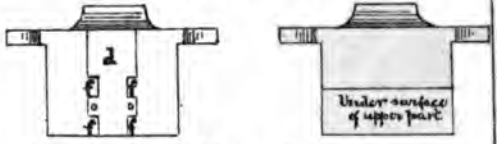
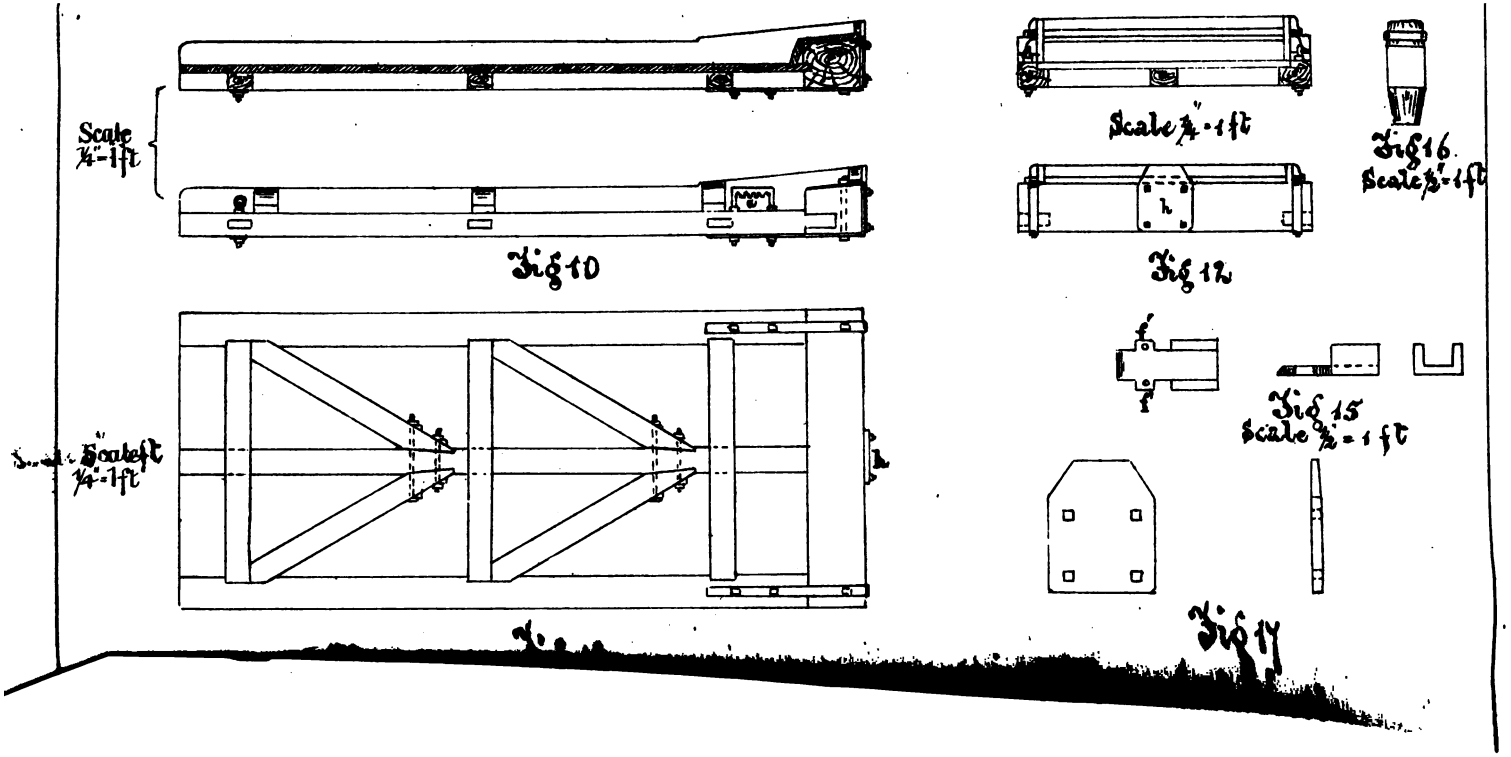
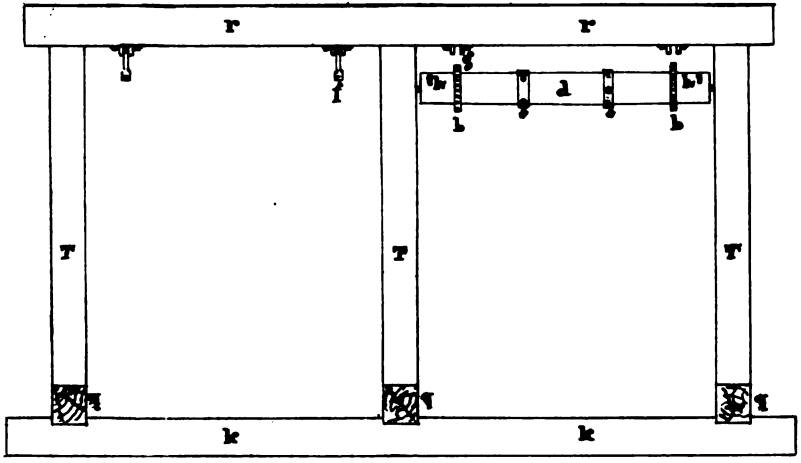


Fig 14

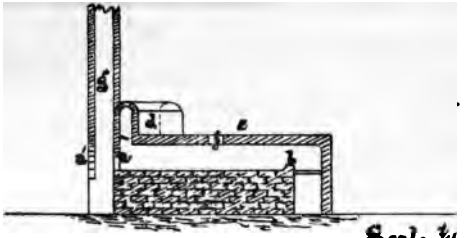

Scale ¼"-1ft
Fig 10
Scale ¼"-1ft
Fig 12
Fig 16
Scale ½"-1ft
Fig 15
Scale ½"-1ft
Scale ¼"-1ft
Fig 14

Scale 1/12 Nat. Size



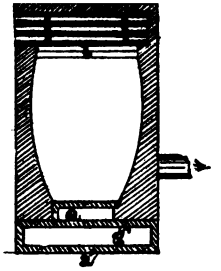
Elevation of Framing at end of Stoss-herd.

Fig 9.



Scale 1/16 = 1 ft

Fig 21



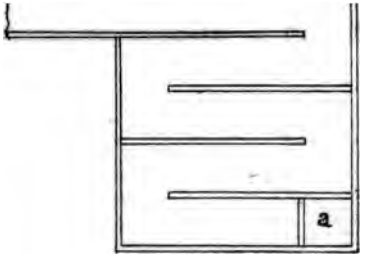


Fig 23
Scale 1/16 = 1 ft

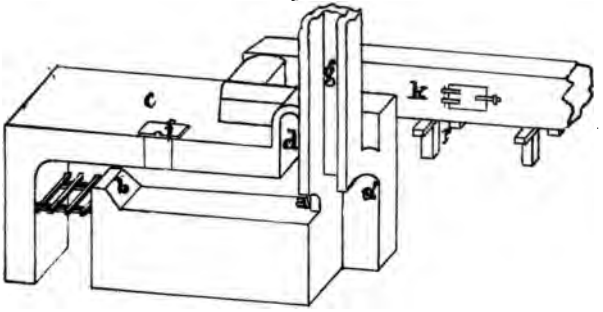


Fig 22

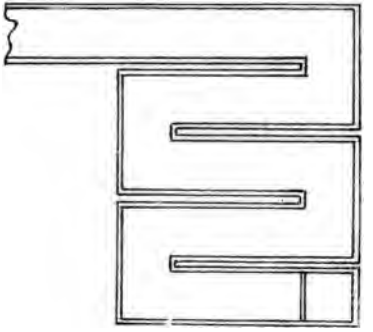
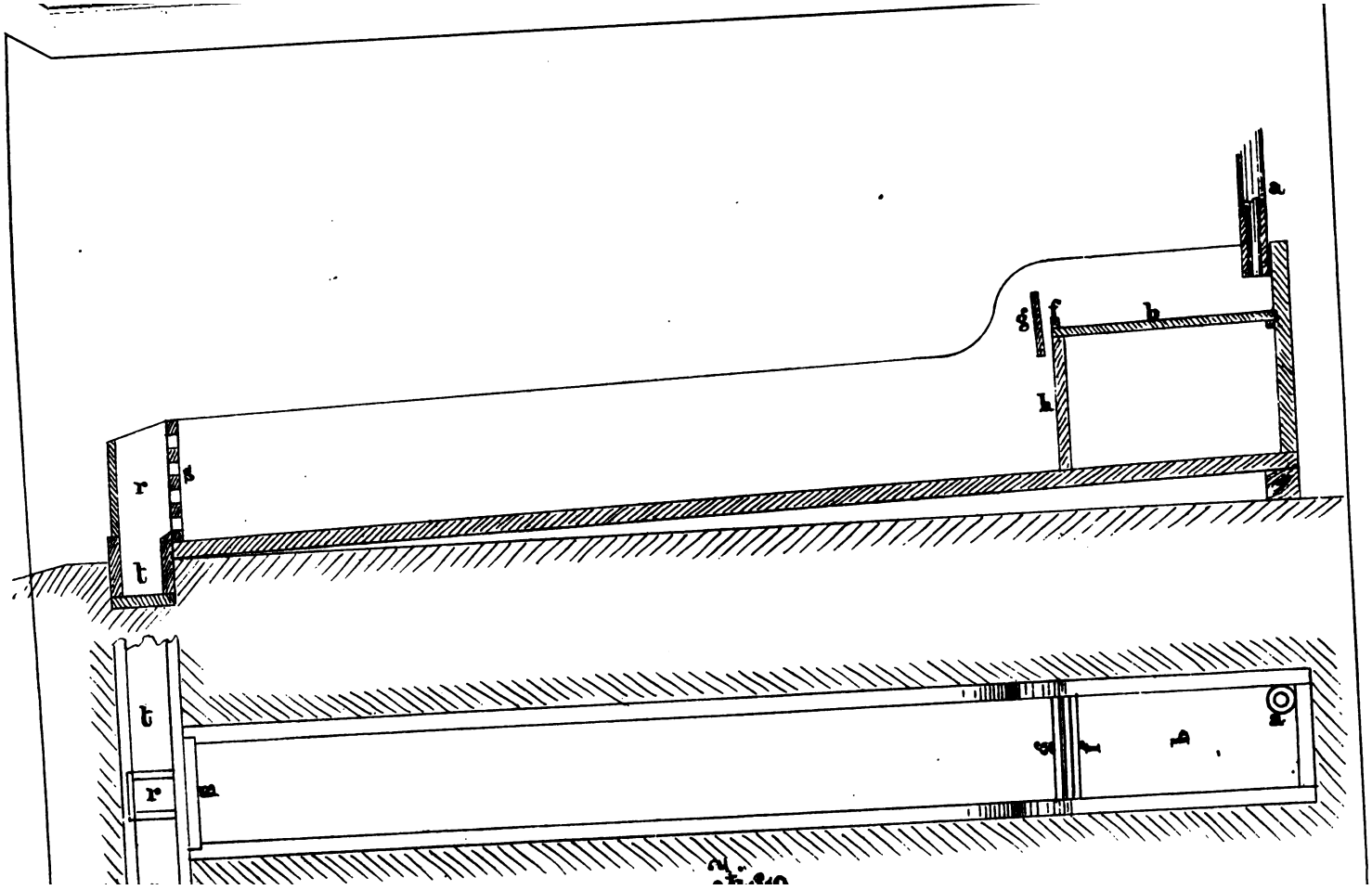
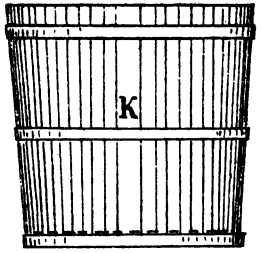
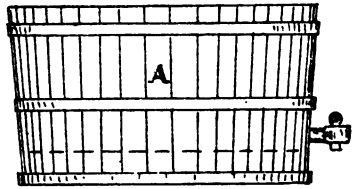


Fig 24

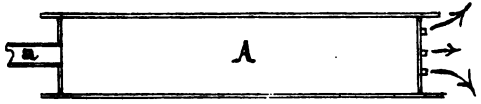

a
g
f
b
h
r
s
t
t
r
m
g
f
b
a

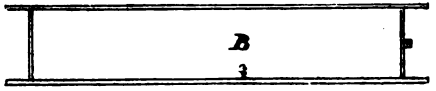




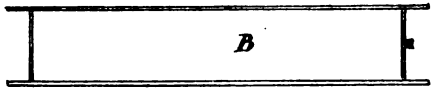
Scale 1/2" - 1 ft

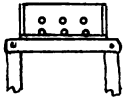
Fig 30





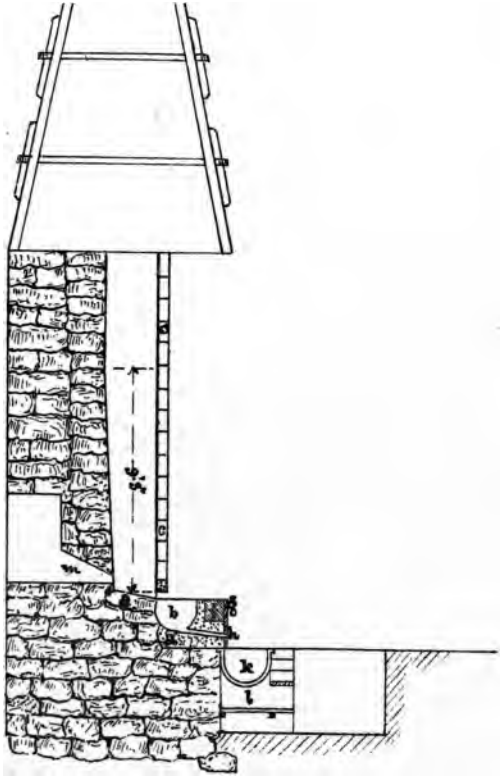
Scale 1/8" - 1 ft





End Elevation of A

Fig 31



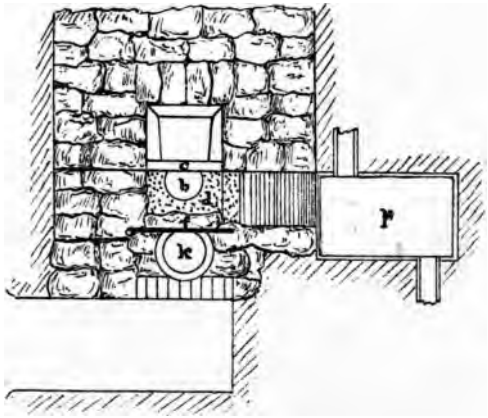


Fig 36

Scale 1/16" = 1 ft

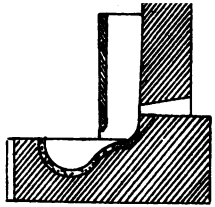


Fig 37

Cogrague & Co. Photo-litho, London.

E. & F. N. Spon, London & New York.

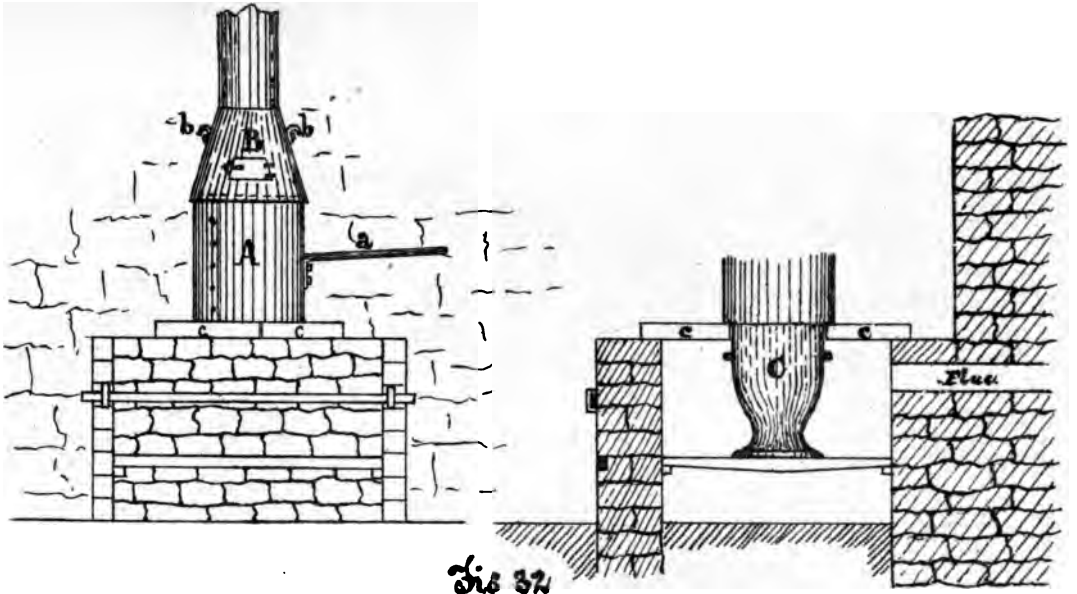


Fig 32

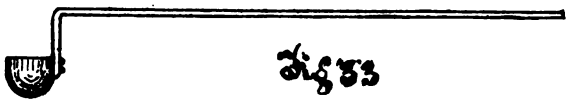


Fig 33

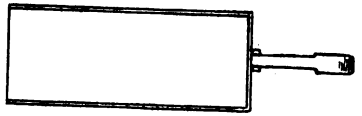


Fig 35

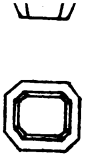


Fig 34

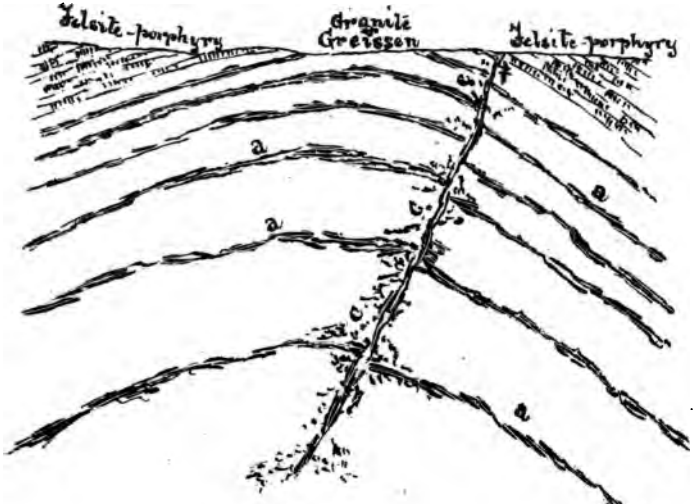


Fig 38

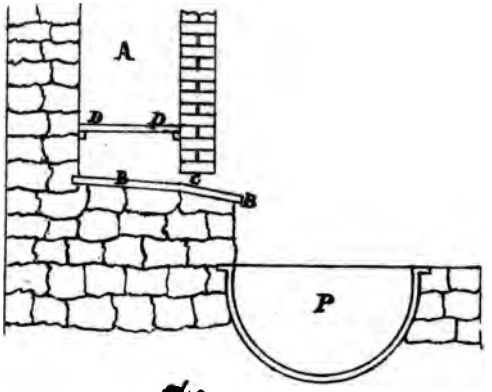


Fig 50

PLATE XII

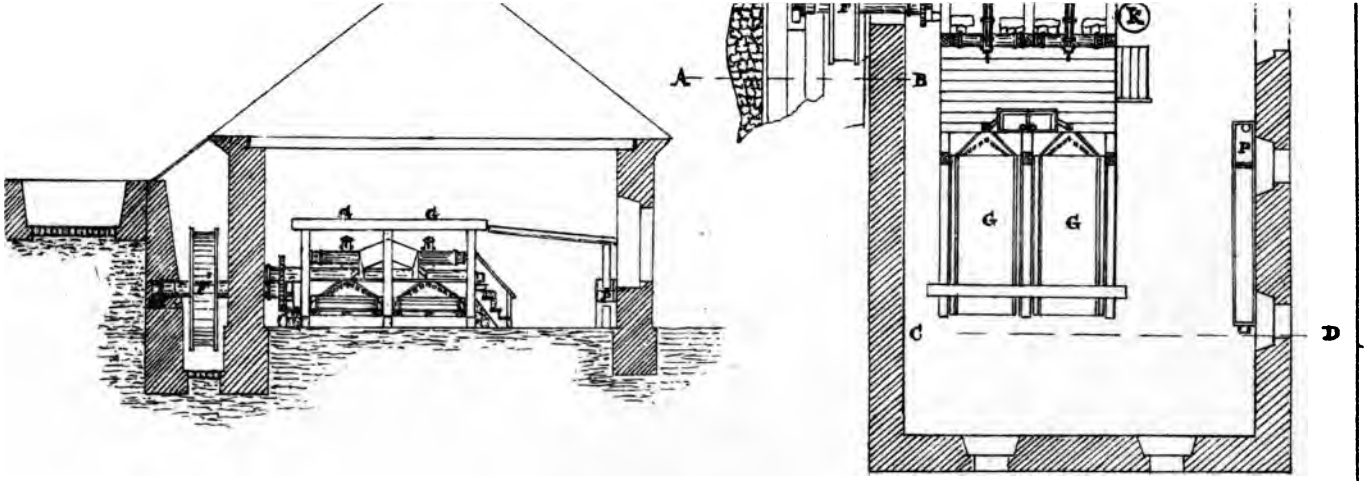


Fig 40
Plan & Section.
of
Wolfram Wasche
Scale 1/16 = 1 ft

J. C. Photo-litho. London.
E. & F. N. Spon, London & New York.

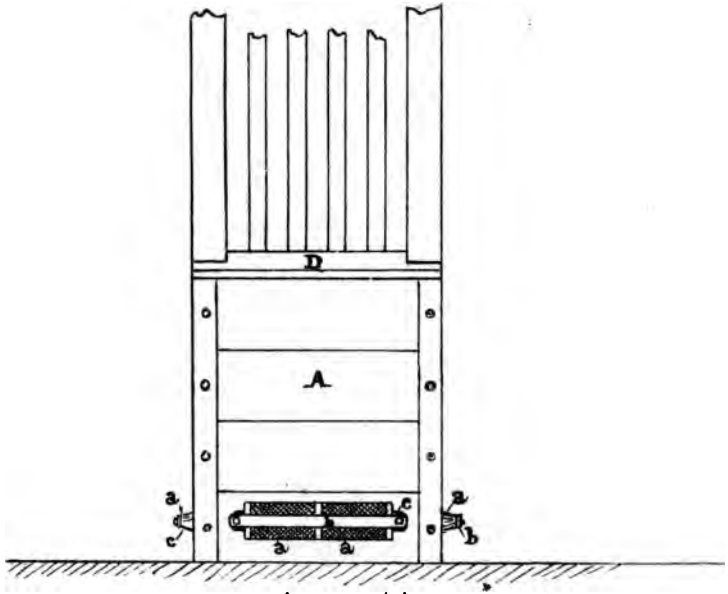
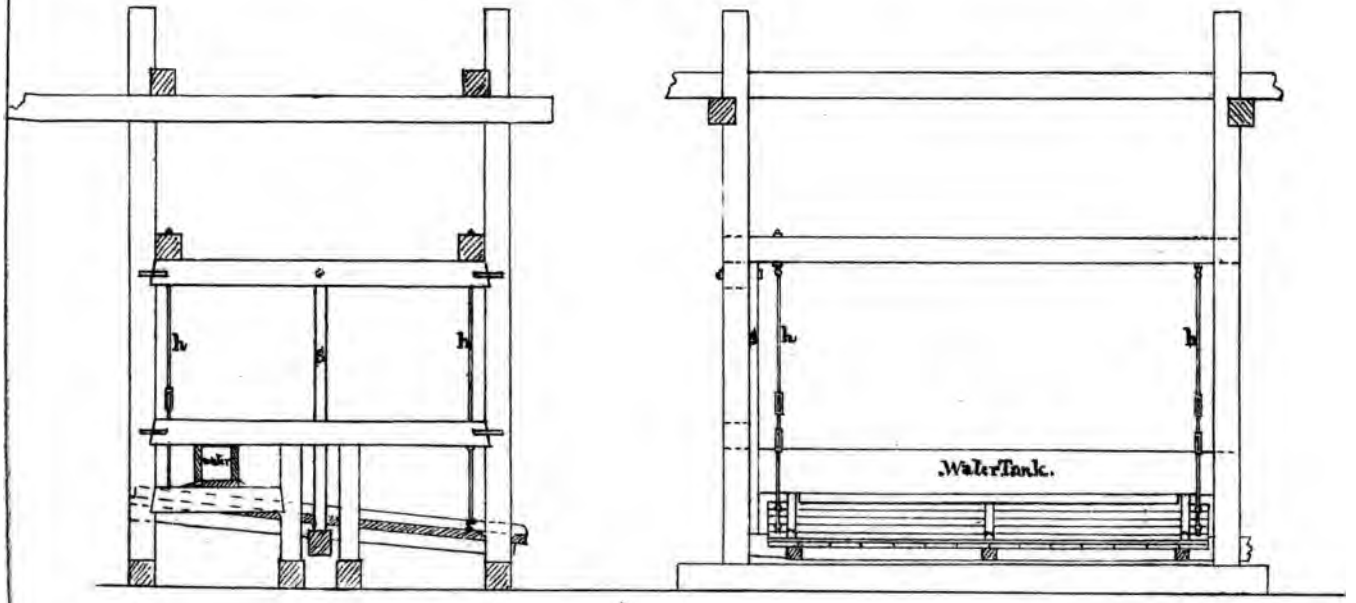


Fig 12 (Scale 3/8" = 1ft)

Fig. 48

Scale 3/8" = 1 ft



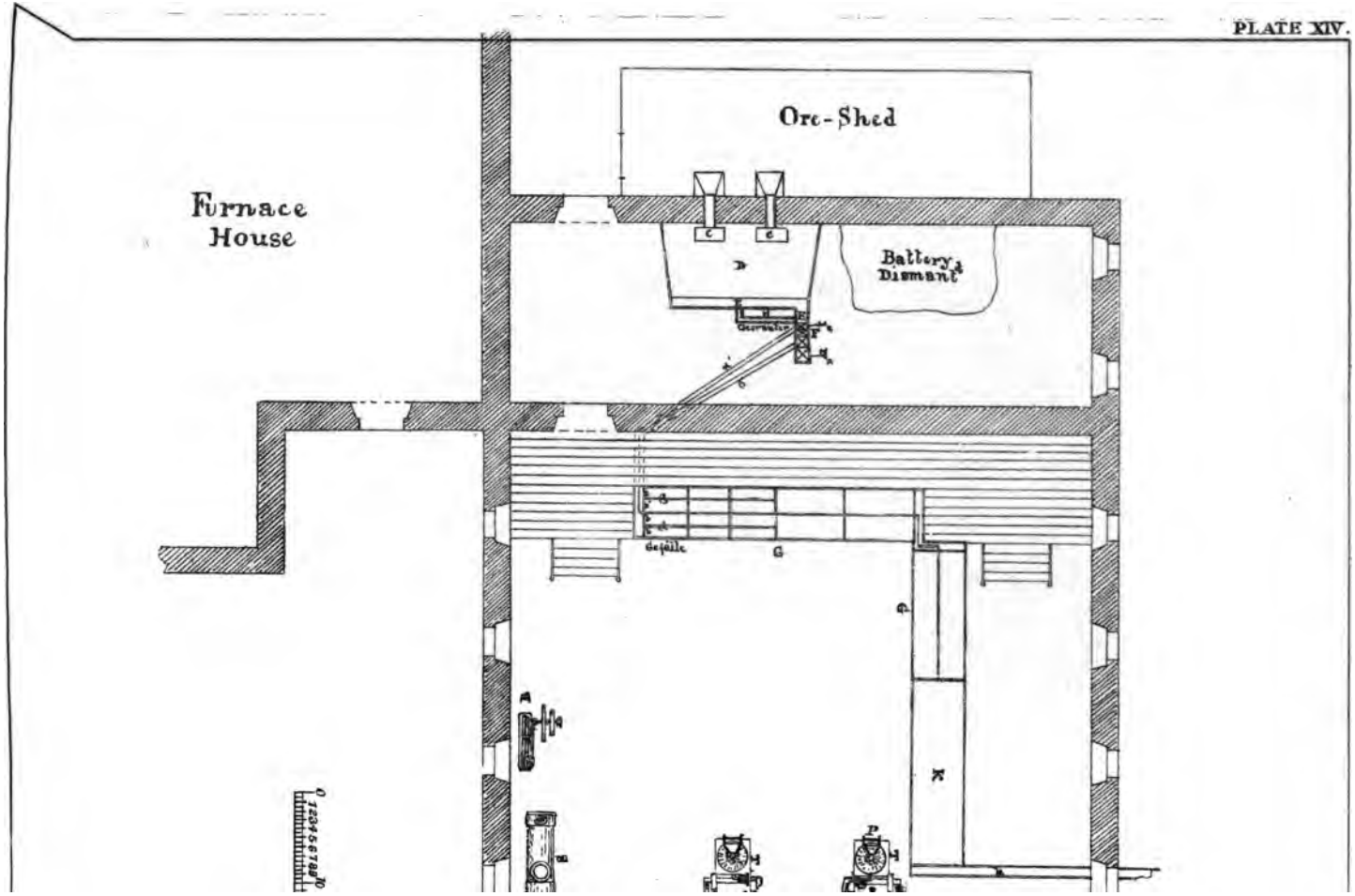
Scale 1/4" = 1 ft

Fig 49

& Co Photo-litho, London

E & F N Spon, London & New York

PLATE XIV.


Ore-Shed
Furnace House
Battery Dismant
Gefälle
G
K
A
B
P
0 1 2 3 4 5 6 7 8 9 10

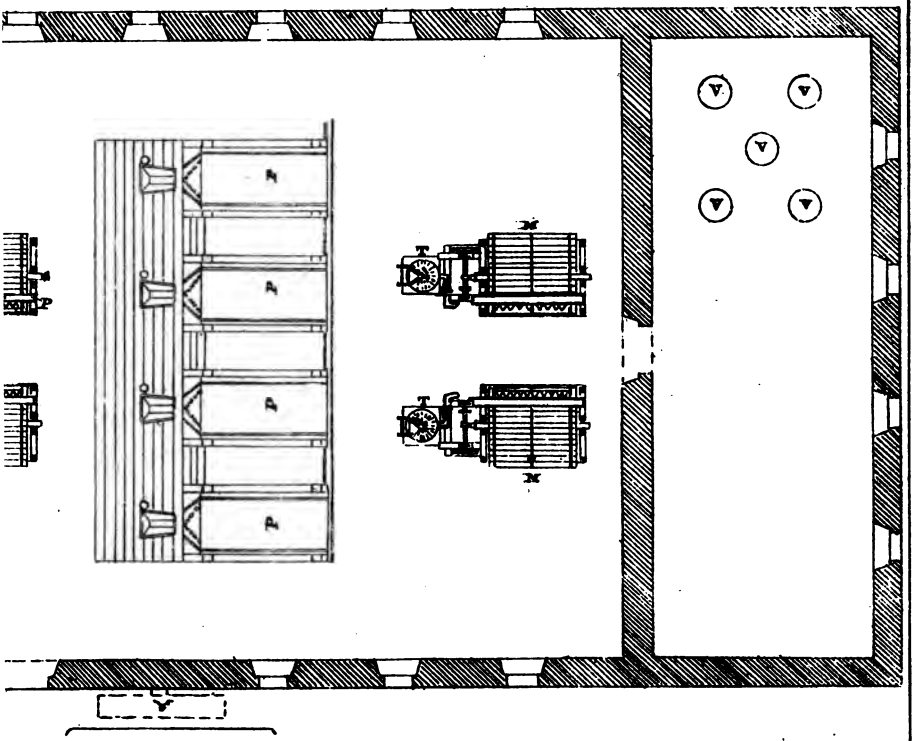


Fig 41

Scale 30 40 50 Ft.

E. & F. N. Spon London & New York
& Co. Photo-litho. London.

BRANNER EARTH SCIENCES LIBRARY

622.34 .C478 C.1
Tin: describing the chief meth
Stanford University Libraries
3 6105 032 235 264

2.34
178

16390